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Development of Intensity- Duration- Frequency Curves for Koforidua

by

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DECLARATION

I hereby declare that this Submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

The estimation of rainfall intensity for a particular frequency is normally required for design of hydraulic and water resources engineering control structures. The main objective of this paper is to develop IDF curves for Koforidua based on recent rainfall information. Annual Maximum Rainfall depths of various durations over twenty-nine years for koforidua were obtained from the Ghana Meteorological Services in Accra. A check for the consistency of data found the data inconsistent and linear regression analysis was used to make the data consistent and also allowed for filling in gaps where data were missing. The data set thus obtained was then subjected to frequency analysis to determine the distribution which best characterize the data set. The annual maximum series were found to be drawn from the Gumbel distribution whose parameters were computed by fitting the statistics to the data. The Kolmogorov-Smirnov test proves the appropriateness of the fitting. The tread follow the usual Intensity-Duration-Frequency-curves and equation has also been developed for particular frequency. By using easy fit software, Gumbel Extreme type one was found to be the best distribution for the analysis. The Intensity- Duration-FrequencyCurves obtained for the study area has generally characteristic form of Intensity-Duration-Frequency-Curves. There should be a revision of the Intensity-DurationFrequency curves for all the major cities and towns in Ghana to take into account the effect of climate change. Meteorological services department must be strengthening in data processing, data collection and storage.

DEDICATION

This project work is dedicated to the Almighty God for his love, care, strength and wisdom throughout my stay on campus. It is also dedicated to my lovely wife Mary Victoria Fordjour and parents Mr. and Mrs. Fordjour.

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ABBREVIATIONS

AMS Annual Maxima Series

CDF Cumulative Density Function (sometimes cdf) E: Expected

Hr hours

IDF Intensity-Duration-Frequency

Min Minutes

Mm millimetres yrs: years

O Observed

UK United Kingdom

USA United States of America

LIST OF SYMBOLS

D or d: duration exp:

exponential function

$f(x)$: probability density function [*pdf*] $F(x)$: cumulative density function [*cdf*] H_0:

null hypothesis I or i: rainfall intensity k: number of constraints ln:

natural logarithm n: number of minutes

N: sample size

s: scale

Parameter T: return period

α level of significance μ:

mean

π: pi value = 3.1458

μ_G: Gumbel mean

μ_s: Sample mean

p_e: exceedence probability X:

random variable

ϑ: skewness coefficient

σ_s: sample standard deviation

μ_N: Gumbel reduced mean X_O:

position μ: reduced variable

σ_G :Gumbel standard deviation

∞ : infinity.

CHAPTER 1: INTRODUCTION

1.1 Background

The most common tool used for planning, designing and operating water resource projects and various engineering projects against flood in water resource engineering is the rainfall Intensity-Duration-Frequency relationship curve. Such relationship was established as early as in 1932 (Bernard, 1932). This relationship is determined through statistical analysis of data of meteorological stations. Quantification of rainfall is generally done using isopluvial maps and intensity- duration-frequency (IDF) curves (Chow *et al.,* 1988). A rainfall intensity-duration-frequency is commonly required for designing of the water resource projects. The intensity duration frequency formulae are the experimental equations which can be expressed as dependent variable, representing relationship among maximum rainfall intensity and other parameters of interest such as rainfall duration and frequency (as independent variables) (Chow *et al.*,1988). IDF curves received considerable attention in engineering hydrology over the past decades. Approaches based on statistical analysis of data were developed, e.g. Bell (1969) and Chen (1983) derived the IDF formulae for the United States. According to Llasat (2001), recent studies are attempting to relate IDF-relationships at meteorological stations to their synoptic meteorological conditions.

1.2 Problem Statement

The recent change in climate due to industrial activities in the past and recent times has been identified as the major cause of global warming. The hydrological cycle has been changed due to the changes in the temperature and precipitation patterns. Projections from climate models suggest that the probability of occurrence of intense rainfall in future will increase due to the increase in greenhouse gas emission (Mailhot and Duchesne, 2010). Such changes in extreme events have enormous ecological, societal and economic impacts in the form of floods, droughts, heat waves, summer and ice storms and have great implications for municipalities. Design standards at present are based on the historic climate information in the form of IDF curves required level of protection from natural phenomena.

However, Koforidua does not have IDF curves and relay on that of Accra for its design under conditions of climate changes, it has become a priority for Koforidua Municipalities to have Intensity Duration Frequency Curves for the City for planning and management to deal with and adopt to changing climatic conditions. Decision makers and stakeholders need to understand the possible effects for developing suitable management decisions for the future. Possible changes may demand new regulations, guidelines for storm water management studies, revision and update of design practices and standards, or retrofitting of existing infrastructure or even constructing additional ones (Prodanovic and Simonovic, 2007). As a result of the above mentioned changes in climate, there is a need to develop Rainfall Intensity Duration -Frequency curves for the study Area.

1.2 Justification of the Project

Designs of urban planning are directly related to climate, especially to the rainfall patterns. Rainfall patterns represented as IDF curves express statistic on reoccurrence frequency of a rain with a given intensity and duration. The precipitation patterns help in the estimation of design storms for the following purposes:

- Design of hydraulic structures such as bridges, drains, reservoir spillways and dams.

- Design of road construction and buildings.

There is a need to improve on the accuracy of design of hydraulic infrastructure because design structures in Ghana is mostly based on the Rational formula ($Q=CIA$).

Rainfall intensity (I) (which has of a functional relationship with duration and frequency in I D F curves) is an important parameter in the rational formula for the determination of surface runoff from the catchment entering into a drainage structure.

1.3 General Objective

The main objective of this project is to develop IDF curves based on recent rainfall information for Koforidua.

1.3.1 Specific Objectives

To analyze rainfall data to obtain maximum rainfall values of different durations. To determine the best probability distribution for the development of IDF curves for the study area.

To develop IDF curves for Koforidua.

1.4 Hypothesis

The extreme rainfall values used in this study are subjected to a Gumbel distribution.

1.5 Organization of the Project

This project is organized as follows: chapter 1 gives an introduction to the study which includes Problem statement, Justification of the Project, General and Specific Objective and hypothesis of the study. Chapter2 consists of two parts; part one presents an overview of literature on IDF with a brief history, properties, and methods of deriving and uses of IDF curves. The Theoretical Principles of Frequency Analysis are detailed in part two .Chapter 3 gives a brief description of the study area, the materials and methods used in the execution of the Project. Chapter 4 deals with discusses of the results. Chapter 5 looks at conclusion and recommendation resulting from the work

CHAPTER 2: LITERATURE REVIEW

2.1 Historical Perspective

Engineers must often consider storm run-off when building a new structure. Rainfall Intensity-Duration-Frequency Curves are used to aid the engineer when creating the design. Engineers have been using IDF curves in the United States since 1935 (Dupont & Allen, 2000). David Yarnell developed the first "intensity-frequency maps" for the United States in 1935.Yarnell studied 30 years of rainfall intensityfrequency .In 1955, the U.S. Weather Bureau (USWB) and the Soil Conservation Service (SCS) defined the depth-area-duration-frequency regime in the United States. "In 1961 the U.S. Weather Bureau published the Rainfall Frequency Atlas of the United States, commonly known as Hershfield"s Technical Paper No. 40 (TP-40). This document contains rainfall depth maps of the United States for the 1-, 2-, 5-, 10, 25-, and 100-year recurrence interval storms for durations of 1-,2-,3-,6-,12-, and 24hours for areas east of the 105° meridian. In February1972 , J.Bdanquah developed IDF curves for various towns and cities in Ghana. Oyebande (1982) established IDF curves for Nigeria. In the 1990"s, some mathematically consistent approaches for IDF development had been proposed. Burlando and Rosso(1996) proposed the mathematical framework to model extreme storm probabilities from the scaling properties of observed data of station precipitation, and the simple scaling and the multiple scaling conjectures was thus introduced to describe the temporal structure of extreme storm rainfall. Koutsoyiannis(1994,1996;1998) proposed an approach to the formulation and construction of the intensity-duration-frequency curves using data from both recording and non-recording stations. IDF curves received considerable attention in engineering hydrology over the past decades. Approaches based on statistical analysis of data were developed, e.g. Bell (1969) and Chen (1983) derived the IDF formulae for the United States. In recent studies, various authors are tempting to relate the IDF-relationship to the synoptic meteorological conditions in the area of the stations (see e.g. Llasat, 2001). In the Sect. 9 of the present paper the results obtained for the three rainfall stations from tropical Central Africa are compared. The Ukkel (Belgium) rainfall intensity data are used here solelyas a basis for comparison (Demaree, 1985; Buishand and Demaree, 1990; Willems, 2000). The comparison between the IDF-curves from three tropical rainfall stations from Central Africa with the maritime temperate station of Ukkel enabled to have a better insight in some of the physical aspects of the modeling.

2.1.1 Use of IDF Curves:

IDF curves are used for the design of hydraulic structures (such as culverts and bridges), roads, and urban drainage systems. In particular, they may be used for;

- Land-use planning and soil conservation studies,
- Management of municipal infrastructure including sewers, storm water management ponds and street curb.
- Design of safe and economical structures for the control, storage, and routing of storm water and surface drainage, Risk ass essment of dams and bridges, esign of roof and storm water drainage systems,
- Flood plain management,
- Soil conservation studies,
- Water-resource management,

The curves can also be used as input to rainfall-runoff models that simulate floods for bridge and spillway design.

 The IDF relationships are used in the rational method to determine the average rainfall intensity for a selected time of concentration (CEC, 2011)

2.1.2 Generation of Rainfall for Different Durations

Sampling of rainfall data for estimating rainfall extremes are commonly proceeded using two approaches: the annual maxima series (AMS) or block maxima and peak over threshold (POT) or partial duration series (PDS)(Coles,2001). Literatures have identified limitations and advantages of both methods. Madsen *et al*. (1997), Buishand *et al*. (1990), Rasmussen *et al*. (1994) found POT to be a better approach than AMS. While Kartz *et al*. (2002), Smith (2003), de Michele and Salvador (2005) suggested use of both methods. By definition, AMS approach includes they early peaks in the observational period while the POT involves all the peak events that exceed a given threshold value. The AMS method is more straightforward. If the number of annual maxima is small (<100), the obtained estimates may be sensitive to outliers. It is an asymptotic method that works well if the number of inputs from which a maximum is considered, is large. Jeruskova *et al*. 2006 showed that convergence to limit any distribution fit can be slow. For determining annual maxima, the maxima of 365 daily values are considered. The seasonal effect may also play a role. Application of POT is somewhat difficult than the AMS because of its selection of an appropriate threshold. For a satisfactory stability of the obtained results, testing of several threshold values such as 90%, 95% and 98% are recommended. Jeruskova *et al*. (2006) have shown that the POT method may work well for short memory series only. For longer data series, the series should be split into several more

Homogeneous groups .Both methods however, have their own disadvantages too; the AMS may neglecter in high values, while the POT may suffer from serial correlation problem (Jervis *et al*., 1936; Langbe in, 1949; Taesombat and Yevjevich, 1978).

2.1.3 Process of Developing IDF Curves

The procedure of developing IDF relationships established on historical rainfall data comprises numerous steps. In general, these steps are well recognized and understood. However, for each major step in an IDF analysis, selection must be made among a number of available systematic tools and techniques since the application of different analytical tools and techniques can produce different results, care must be taken to assure that the most appropriate tools and techniques are selected for use. The basic process for developing IDF curves is described in the five steps presented below;

2.2 Source of Raw Data

Raw rainfall data can be obtained from a rain gauge either by using a recording or non-recording bucket, which gives the cumulative depth of rainfall with time. Incremental rainfall observation data can be obtained either through local source or through the Ghana meteorological services department sources. Rainfall observation data are usually collected in hourly increments, although sub-hourly rainfall observations may be accessible in some locations. General rules of thumb exist for choosing the appropriate length of record for analysis. These include setting 10 years as a minimum length of record, and setting the minimum length of record equal to half of the maximum recurrence interval for which IDF analyses will be performed (Wurbs, 2003; CEH, 1995). If climate stability can be assumed, a longer period of record is preferred over a shorter.

2.2.1 Identification of Extreme Events

After finding the raw data, the most extreme rainfall events happening over selected durations within each year are recognized. A set of durations is typically selected that is skewed towards the shorter durations in order to obtain data that will correctly represent the relationship between duration and intensity for shorter duration storms.

Categorized lists of the extreme events from each year are then created for each selected storm duration. The rated lists are referred to as annualmaximum series. An alternative is to identify partial-duration series, which are rated lists of the *n* maximum rainfall amounts within a period of n years of record. This allows the documentation of more than one extreme event within a given year; Use of partial-duration series requires additional labor and precludes the application of some statistical distributions.

2.2.2 Performance of Probability Analyses on Extreme Events

The series of extreme events recognized in step2 above are each fitted to a statistical distribution in order to estimate the likelihoods connected with events of differing magnitudes. Recognizing that the return interval of a storm is the transposed of its likelihood of occurrence, the fitting of a statistical distribution also allows for the calculation of the magnitude of the storms correlated to particular return intervals and the calculation of return interval of storms of given magnitudes. There are numerous statistical distributions to choose from in order to compute the probabilities of events. Moreover, there are numerous different approaches of fitting the statistical distributions to the series, referred to as parameter estimation techniques.

2.2.3 Plotting of results

Once Steps 1,2, and 3 have been executed for each storm duration, plots can be made showing the relationship between rainfall and return interval along lines representing storms with durations equal to those selected in Step2" However, IDF curves are more useful when they a represented as lines representing specific return intervals, In Order to create graphs with lines demonstrating specific return intervals, individual point values must be calculated based on likelihood relationships established inStep3,.

2.2.4 Performance of Regression Analysis on IDF Results

Because point values by themselves are of limited utility, it is often preferable to execute the regression analysis on IDF results in order to develop mathematical relationships between storm duration magnitudes for each calculated return interval.

Smooth IDF curves generated by use of Regression Analysis are used by storm water professionals for analysis. The curves are significantly beneficial to them both graphically and mathematically during their analysis. Additional benefit of curve fitting include being able to extrapolate IDF values for durations shorter than those available in the raw data.

There are several methods available to perform regression analysis which is based on the theoretical principles of rate of recurrence analysis. The best method used depends on the nature of the data and often several methods must be tried and compared to one another in order to identify the best choice (Anchorage IDF curves.pdf, 2006).

2.3 Distribution used for IDF Curves

a) Exponential Distribution

When events which happen independently and instantaneously on a time horizon or along line, such as the occurrence of precipitation, a sequence of hydraulically event, may be considered as a Poisson process. The time interval (or interarrival time) of such events may be described by an exponential distribution with a parameter λ, defined as the average occurrence of these events. Random shocks to hydrological systems can be described using the exponential distribution. The strength of the exponential distribution lies in its easy ability to estimate λ from observed data and It lends itself well to hypothetical studies, such as a probability model for the linear reservoir $\left(\lambda = {}^{1}\!/_{k}\right)$, where k refers to storage constant of the linear reservoir. The condition of occurrence of each event to be totally independent of its neighbors is a disadvantage of the exponential distribution because this assumption may not be hold for the process under study.

b) Gamma Distribution

The gamma distribution can be described as the time taken for a number β of events to happen in a Poisson process, which is the distribution of a total of β independent and identical exponentially distributed random variables. The smoothly varying nature of gamma distribution makes it useful in explaining how skewed the hydrologic variables will be without the need for log transformation. The gamma distribution can be used to describe the distribution of depth of precipitation in storms. With the gamma distribution the following parameters are involved $\Gamma(\beta)$, which is given by equation (2.1) and (2.2)

$$\Gamma(\beta) = (\beta - 1)! = (\beta - 1)(\beta - 2) \tag{2.1}$$

$$\Gamma(\beta) = \int_0^\infty u^{\beta-1} e^{-u} du \tag{2.2}$$

The shortcoming of the gamma distribution is that the two parameters β *and* λ have a lesser bound at zero, which is a limitation in hydrologic applications where variables have a lesser bound larger than zero. This limitation also applies to IDF analyses where maximum intensity values used have lower bound larger than zero.

c) Pearson Type III Distribution

The three parameter gamma distribution which is also recognized as Pearson type III distribution, introduces a third parameter, the lower bound ϵ, so that the standard deviation, the coefficient of skewness and the average can be transformed into three parameters λ, β *and* ϵ of the probability distribution. The parameters λ, β and ϵ can vary allowing the distribution to assume different shapes which makes it a very flexible distribution.

There are seven types of the Pearson system of distributions; they are all solutions of $f(x)$ in an equation of the form;

$$d\left[\frac{f(x)}{dx}\right] = \frac{f(x)(x-d)}{C_O+C_1+C_2{}^{X2}} \qquad (2.3)$$

Where d can be described as is the mode of the distribution $f(x)$ is maximum and $C_O, C_1, and\ C_2$ are coefficient to be determined. When $C_2 = 0$, the solution of eqn.(2.3) is a Pearson Type III distribution. The distribution was first adopted by Foster in 1974 in hydrology to describe the probability distribution of annual maximum flood peaks. It has a drawback when the data is skewed positively.

d) Log- Pearson Type III distribution

In the United States of America, Log-Pearson Type III distribution is a standard distribution for the analysis of annual maximum floods. It states that given the condition that log X follows a Pearson Type III distribution, it implies that X is said to have adopted a log-Pearson Type III distribution. The location of the bound ϵ in the log-Pearson Type III distribution depends on the skewness of the data. The Limitation with log-pearson Type III distribution is that if the data are skewed positively, then $\log X \geq \epsilon$ and ϵ is the lesser bound and if the data is skewed negatively, and $\log X \leq \epsilon$ ϵ is an higher bound.

The resultant logarithmic transformation reduces the skewness of the transformed data and may produce data which are may be negatively skewed from the original data which is usually skewed positively.

The application of the log-Pearson Type III distribution would impose an artificial upper bound on the data. Again, the log-Pearson Type III distribution requires a lot data to fix the value of the shape parameters (λ, β) and the bound (ϵ) of the distribution.

e) Extreme Value Distribution of Gumbel

Extreme maximum and minimum values such as annual maximum and minimum discharge of a given location from a historical data are selected and statistically analyzed.

When the count of extreme values selected are large, the probability distribution of the extreme values may converge to one of the three forms of extreme value distributions called Types I, II and III respectively. The General Extreme Value which in three forms that is E V Type I, II, and III have limitation. The probability distribution function for the GEV is;

F (x) =exp $\left[-\left(1 - kx - u/\alpha\right)^{1/k}\right)\right]$ (2.4)

Where k, u and α are parameters to be determined. The three limiting cases are

- For $k = 0$, E V I distribution.
- $k < 0$, For E V II distribution for which (2.4) applies for

$(u + \alpha/k) \leq x \leq \infty$

- For $k > 0$, E V III distribution for which (2.10) applies for

$-\infty \leq x \leq u + \alpha/k$.

In all the three cases, there is an assumption that α is positive. For the Extreme type I value distribution x is boundless, while for Extreme type II value, x is bounded from below by $u + \alpha/k$, and for the EV III distribution x is bounded from above by $u + \alpha/k.$

A variable x is said to have a Weibull distribution if it is described by the extreme value type III.

There are three asymptotic forms of the distributions of extreme values, named Type I, Type II, and Type III respectively. The extreme value Type I (EV I) probability distribution function is;

F(x) = exp $\left[-\exp(-\frac{x-u}{\alpha}\right]$ -∞ $\leq x \leq$ (2.5)

The parameters are estimated as;

$\infty\sqrt{6\, s/\pi}$ (2.6)

The parameter u is the mode of the distribution (point of maximum probability density). A reduced variate y can be defined as;

$y = \frac{x-u}{\propto}$ (2.7)

Substituting the reduced variate into (2.11) yields $F(x) = exp[-exp(-y)]$ (2.15).

Solving for y: $y = -\ln\left[\ln\left(\frac{1}{F(x)}\right)\right]$ (2.8)

Equation (2.16) is used y to define for the Type II, and Type III distributions.

The values of $x \ and \ y$ can be plotted. For the EV I distribution, the plot is a straight line while, for large values of y, the corresponding curve for the EV II distribution slopes more steeply than for EV I, and the curve for the EV III distribution slopes less steeply, being bounded from above. Extreme value distributions have been widely used in hydrology. They form the basis for the standardized method of flood frequency analysis in Great Britain. Storm rainfalls are commonly modelled by the extreme value Type I (Gumbel) distribution and drought flows by the Weibull distribution, that is the EV III distribution applied to $-x$.

The extreme rainfall values used in this study are subjected to a Gumbel distribution. For maxima extremes frequency analysis the Gumbel and the logPearson distribution functions are recommended. As the former is a two-parametric function it is more advantageous than the latter for it does not require a lot of data to determine all the parameters. Gumbel distribution is recommended when frequency analysis is performed on an individual gauge records because data are not enough to determine the shape parameter.

2.4 Gumbel Distribution

Gumbel distribution is a statistical method often used for predicting extreme hydrological events such as floods. The Extreme Value type I (Gumbel) distribution is used extensively in flood studies in the UK and in many other part of the world.

If the equations 2.10 and 2.11 define the cumulative distribution function and probability density function of a random variable (X), then X is said to follow a Gumbel distribution:

$$F(x) = \exp\left(-\exp\left(-\frac{X-x_o}{s}\right)\right) \quad s \neq o \qquad (2.9)$$

$$f(x) = \exp\left(-\exp\left(\frac{X-X_O}{s} - \exp\left[-\frac{X-X_O}{s}\right]\right\}\right. \qquad (2.10)$$

Where the scale parameter s, and position parameter x_0, are given as □□□ □□□ □□□

□□□x ; x_0 s□ 0

The mean is defined by Equation 2.12 with Equations 2.13 and 2.14 the variance and the skewness coefficient for the extreme-value type I distribution.

$$\mu_G = X_0 + 0.577216 \text{ x } s \quad (2.11)$$

$$\sigma_G^2 = \frac{\pi^2}{6} \text{ x } s^2 \quad (2.12)$$

$$\vartheta = 1.139 \quad (2.13)$$

Using the following transformation $u = \frac{x - x_0}{s}$ the Gumbel distribution can be expressed in equation (2.15) and (2.16) as cumulative distribution function and probability distribution function (pdf).

$$F(u) = \exp[- \exp(-u)] \quad (2.14)$$

$$f(u) = \exp[-u - \exp(-u)] \quad (2.15)$$

In extreme events such as flood flows or maximum rainfall, cumulative distribution function is most useful in determining the quartile for a given frequency or return period.

2.4.1 Frequency factor

When the Gumbel statistic has been fitted to the sample, any extreme value related to a return period greater than or equal to two years ($T \geq 2$ years), is found by the formula

$$X_T = \mu_G + K_T \text{ X } \sigma_G \text{ (Chow, 1964)} \quad (2.16)$$

Where σ_G and μ_G are standard deviation and Gumbel average of the population, K_T is the coefficient factor depending on a certain return period T

$$K_T = -\frac{\sqrt{6}}{\pi}\{ 0.577216 + \text{In}\left[\text{In} \left(\frac{T}{T-1} \right) \right] \} \qquad (2.17)$$

For T < 2 years T= $K_T = -\frac{\sqrt{6}}{\pi} X [0.5772 - \text{InT} + \frac{1}{2\,X\,T} + \frac{1}{24\,X\,T^2} + \frac{1}{8\,X\,T^3}]$ (2.18)

2.5 Statistical Series

After selecting the storm durations that are to be analyzed, the first major decision that must be made during an IDF analysis is whether to use an annual-maximum series or a partial-duration series. An annual-maximum series can be defined as a ranked list of the maximum rainfall amounts that have occurred over a specified duration during each year of record. A partial-duration series, on the other hand, is defined as a ranked list of the n maximum rainfall amounts within a period of *n* years of record For example, for a period of record that is 20 years in length, an annualmaximum series would consist of the most intense storms of *X* duration that occurred within each year. A partial-duration series would simply identify the 20 most intense storms of *X* duration that occurred any time within the20-year period of record. In both cases the series includes 20 rainfall events. However, the annualmaximum series only identifies the biggest storm in each year: Therefore, if several of the largest events occurred within a single year within the 20-year period of record, all but the largest of these would be excluded from the series and thus be excluded from the IDF analyses. The result of this exclusion is often manifested in IDF curves indicating artificially low intensities for frequent storms of short duration. The use of an annual-maximum series is common in the performance of IDF analyses. However, it is felt that the use of a partial-duration series would be more appropriate for the purposes of updating Anchorage"s IDF curves. This is because the IDF relationships for short duration storms are regularly used by the engineering community in Rational Method analyses for small sites ,and the use of IDF curves that present artificially low intensities for frequent storm events will likely result in under-sizing of storm drainage infrastructure.(*Anchorage IDF curves.pdf*, 2006)

2.5.1 Moments of probability distributions.

A probability function defines the relationship between the outcome of a random process and the probability of its occurrence. A probability function defined over a discrete sample space is called discrete probability distribution function otherwise the probability function is continuous (continuous probability distribution function). The following review will be limited to continuous probability distribution.

If X is a continuous random variable so that $P(a \leq x \leq b) = \int_a^b f(x)dx$ and if $f(x)$satisfies the following c onditions: $f(x) \geq 0 \ \forall x$

And

$$= \int_{-\infty}^{+\infty} f\ (x)dx \qquad = 1 \tag{2.19}$$

$f(x)$ is the probability density function *(pdf)* of the random variable

Its cumulative distribution function *(cdf)* is defined as follow $F(x) = p(X < x)$

$$F(x) = \int_{-\infty}^{x} f\ (x)dx \tag{2.20}$$

The expected value of a random g function is given by

$$< g > = \int_{--\infty}^{+\infty} g\ (x) f\ (x)dx \tag{2.21}$$

2.5.2 Skewness or third moment of the probability distribution

The skewness or the skewness coefficient measures the symmetry of the *pd f* about the mean; it is given by the expected value of the function $g(x) = \frac{(x-\mu)^3}{\sigma^3}$

$$\vartheta = \frac{1}{\sigma^3} \int_{-\infty}^{+\infty} (x - \mu)^3 \ f(x) dx \quad (2.22)$$

The variables measures the mean, the variability about the mean and ϑ the symmetry about the mean of a statistic population.

2.6 Empirical IDF Formulas

The empirical method can be used to establish the relationship between rainfall intensity, it duration and return period is shown by the equations below. From literature, there were several functions found in hydrology application, this are the basic forms of equation used to express the rainfall intensity duration relationship are summarized in equation (2.23),(2.24), (2.25)and (2.26).(Chowetal,1988)

Talbot $i = \frac{cT^m}{d+b}$ (2.23)

Bernard $I = \frac{cT^m}{d+b}$ (2.24)

Kimijima $I = \frac{cT^m}{d^e}$ (2.25)

Sheman $i = \frac{cT^m}{(d+b)^6}$

(2.26) Where „I" refers to intensity; T return period in Year"s and d is the duration (minutes); c, b, e and m are the constant parameters associated to the metrological conditions. Empirical equations have been widely used for hydrology practical application. The equations have shown that rainfall intensity decreases with increase in rainfall duration for a given return period. (Jaleel & Maha Atta Farawn, 2013).

2.7 Mean or first moment of the probability distribution

If $g(x) = x$; $< g >$ is the mean of the random variable X:

$$< x > = \int_{-\infty}^{+\infty} (x - \mu)^2 \ f(x) \ dx \quad (2.27)$$

b) Variance or second moment of the probability distribution

If $(x) = (x - \mu)^2$; $< g >$is the variance of the continuous random variable X:

$=\sigma^2=\int_{-\infty}^{+\infty}(x - \mu)^2$ f(x) dx (2,28) The deviation of the random variable from the mean (5) is measured by the standard deviation σ = $\sqrt{\sigma^2}$ (2.29)

2.8 Test of goodness of fit

To account for the validity of the fitting of the probability distribution, a test of goodness of fit is required. Various criteria could be employed to evaluate the suitability of a probability distribution for describing a set of data. Statistical goodness-of-fit tests as well as graphical display such as probability plots are effective way to determine whether the fitted distributions are consistent with the given set of observations. In addition, the predictive ability of a model is important in applying the model for prediction of future event. Often in selecting a particular distribution, be tempted to select a distribution with large number of parameters. Generally, the more parameters a distribution as, the better it will fit to the data.

However, difficulty in the parameter estimation a rises and the distribution may be too rigid to accurately extrapolate beyond the range of the available data. Regression, Probability transformation and Special features tests are used to test the goodness of fit. Probability plotting is the most common form of regression test, where the sample data are rearranged in an order and plotted on a graph. The data which conform to the selected distribution will lie on a straight line. The deviation of the data from linearity is visually assessed. In goodness of fit test, it is recommended that other tests of fit should always be improved by a probability plot. An informal visual test, a variation of the probability plotting, is done by visually comparing a plot of the relative frequencies and probability density function of the sample data on the same graph.

Among the goodness-of-fit tests, the chi-square test is oldest. It is less subjective. In the chi-test, the sample data can be divided into a count number of intervals and the number of data points falling in each interval is compared with the expected number predicted by the fitted distribution. With the chi-square test, the anticipated number is obtained by adding the fitted probability distribution between the boundaries intervals and multiplying by the number of data points in the sample. Although this analysis can be used for continuous random variables, its use is recommended for categorical and numerically discrete random variables because for a continuous random variable, there are an infinite number of ways to partition the support (the set of possible values) of the variable, and the choice of the number of intervals is not unique.

Although the chi-test is less subjective than the visual test, it is not completely objective. In the Chi- test statistic it depends on the lengths and number of the intervals. There is no one rule universally accepted for choosing either. An equiprobable interval with the expected number in individual are recommended. The difference between Anderson Darling statistic and Cramer-von Mises test statistic is that, Anderson-Darling statistic can be described as weighted sum of deviations, with more emphasis given to the observations in the tails of the distribution, while Cramer-von Mises test statistic considers the sum of the squared deviations from the goodness of fit line.

2.8.1 Description of Types of Goodness-of-Fit Test a) Chi-Square Test$\chi^2(\nu)$ The fowling steps will be carried out to make the chi-square test:

Step 1: The frequency of both variables i.e. the observed data (O) and their expected values (E) are determined. This is done by putting the O and E into intervals, best expressed by histogram of frequencies.

Step 2: The classification are rearranged such that the minimum expected frequency in class become equal to or greater than five (5). Classes with frequencies less than five are then merged.

Step 3: The chi-square value for all intervals are then calculated using Equation 2.30 below.

$$x^2(t) = \sum_i^n \left(\frac{O_i - E_i}{E_i}\right) 2 \qquad (2.30)$$

Where t = M –k-1, is degree of freedom

M= Intervals and k = population parameters measured from the sample statistics; M and k are constraints imposed on the fitting process.

Step 4: the T values obtained are compared to the chi-square value $\chi^2_{0.95}$ from tables. The null hypothesis will be accepted if equation 2.31 is satisfied and rejected if otherwise $X_{.2} < X^2{}_{0.95}$

2.8.2 Kolmogorov-Smirnov Test

The Kolmogorov-Smirnov test defers from the chi-square test. The former is done on cumulative distribution function whereas the latter is done on probability distribution. The Kolmogorov-Smirnov test is applicable only to continuous distribution functions. In the Kolmogorov-Smirnov test the following process are involved:

1 Let $F_0(x)$ be the sample cumulative distribution function based on *N* Observations. For any observed $x,\ F_0(x) = \frac{j}{N}$, where *j* is the number of observations less than or equal to *x*.

2. Let $F_t(x)$ be the specified theoretical cumulative distribution function under the null hypothesis.

3. Maximum deviation will be determined by Equation (2.31).

D = max $|F_O(x) - F_t(x)|$ (2.31)

The hypothesis is rejected if, for the chosen significance level, the observed value of D is greater than or equal to the critical value of the Kolmogorov-Smirnov statistic.

2.8.3 Anderson-Darling test

The Anderson-Darling test known as empirical distribution statistics (EDF) the purpose is to measure the difference between the empirical distribution function of given data and hypothetical distribution to be tested. It can also be designed to analysis the continuity of a cumulative distribution function $F_x(x, \theta)$ where x refers to a $(\theta = \mu, \sigma^2)$ random variable and θ is a vector of one or more parameters entering into the distribution. For a normal distribution, the vector is given as where μ is the average and σ the standard deviation of the distribution. $F(x, \theta)$ Or $F(x)$ will be written for $F_x(x, \theta)$ if there is no ambiguity. The empirical distribution can also be defined as $F_n(x)$equal to the ratio of sample less than (x) and a family of statistics measuring the variation between $F_n(x)$ and $F(x, \theta)$ is the Cramer–von Mises family.

$$=w^2{}_n = n \int_{-\infty}^{\infty} [F_n(x) - F(x, \Theta^2)]\, \psi(x) dx \quad (2.32)$$

In the tails, the statistic is a recommended one with generally good power over a wide range of alternative distributions when $F(x, \theta)$ is not the true distribution?

Anderson-Darling test statistic can be calculated from equation (2.33) and (2.34) below.

Z_i = F ($x_{(i),\theta}$) (i =1, ...n) (2.33)

$$A^2 = \sum_{i=1}^{n}\{(2i-1)[\ln z_i + \ln(1 - z_{n+1-i}]\}/n - n \quad (2.34)$$

The A^2 statistic was introduced by Anderson-Darling and for CASE O, the asymptotic distribution and a table of percentage points was given. A bad fit is assigned to A^2 with large values. The distribution of Asymptotic theory for a finite sample quickly approaches the asymptotic distribution and for practical purposes, this distribution can be used for sample sizes > (greater) than 5.

2.8.4 Asymptotic theory of the Anderson-Darling statistic

It states that if A^2 is a function of ordered uniform random variables, then the distribution of A^2 for case 0 is the identical for all distributions that were tested. This is because equation 2.33, a probability integral transformation with z_i values are considered ordered values from a uniform distribution with limits that range between 0 and 1. When θ contains unknown components, the z_i given by the transformation in eqn.2.33 using $\hat{\theta}$ instead of θ will not be ordered uniform random variables and the distribution theory of A^2 (as for all other EDF statistics) becomes substantially more difficult. In general, the distribution of Asymptotic theory will be depended on n and also on the values of the unknown parameters. Fortunately, an important simplication occurs when unknown components of θ are the location and scale parameters only. Then the distribution of an empirical distribution statistics with an estimate of θ will be depended on the distribution tested but not on the precise values of the unknown parameters. The simplication makes it worthwhile to calculate the asymptotic theory and percentage points for A^2 for special distributions with location and scale parameters and this has been done for normal and exponential, extreme value Weibull distribution, logistic distribution and gamma distribution with unknown scale parameter but known shape parameter. To test for goodness-of-fit test for any distribution, the foremost step (Cramer-Van Mises and Anderson-Darling test) is to calculate approximately the unknown parameters. And can be done by using highest probability for the modification and asymptotic theory to stand. Assuming that θ^* is the vector of the parameters, with any unknown parameters calculated above. Vector θ^*replaces θ in eqn.2.32. To give the , and is always calculated from eqn.2.33. It is then compared with the percentage points from tables. With Asymptotic theory, the null hypothesis will be rejected if random variable X has the distribution function $F(x,\theta^*)$exceeds the

appropriate percentage point.

2.8.5 Cramer-Van Mises Test

The Cramer-Van Mises statistic W_n^2 is generally defined to be the statistic,

$$=w^2{}_n = n \int_{-\infty}^{\infty}[F_n\,(x) - F_o\,(x)^2]\;dF_o\,(x) \qquad (2.35)$$

where $F_o\,(x)$ = hypothesized cumulative distribution function (CDF)

$F_n(x)$ = the sample or empirical CDF based on the sample $x_1, \dots . x_n$.

It is used to test the null hypothesis $H_o{:}F\,(x) = F_o\,(x)$ where there is an assumption that the sample draws from a population with CDF$F(x)$. This can also be used as an alternative to the chi-squared goodness-of-fit test with the requirement that data have to group before computation.

For the evaluation of the statistic, let $t_i = F_o\left(x_i^{'}\right)$ where $x_1^{'} < x_2^{'} < \cdots < x_n^{'}$the original ordered observations, then; are

$$W_n{}^2 = \sum_{i=1}^{n} \left[t_i - \frac{2i\ 1}{2n} \right] 2 + \frac{1}{12n} \tag{2.36}$$

For large W_n^2 values, the null hypothesis H_o is rejected in favour of $H_1 \neq F_o(x)$. If hypothesized cumulative distribution function is measured, the null distribution of Cramer-Van Mises is independent. Of F_o.

None of the two tests (Anderson-Darling test and Cramer-Van Mises test) do not agree or have a common consensus in the hydrologic distribution of data. The variation in agreement may possibly be due to some complications that arise due to unknown parameters of the hypothetical distribution.

CHAPTER 3: STUDY AREA AND METHODOLOGY

3.1 Study Area

The New Juaben Municipality is one of the Municipalities in the Eastern Region and was established in1988 by the Legislative Instrument (LI) 1426. The Municipality lies between longitudes 1030‟West and 0030 East and latitudes 60 and 70 North. The Municipality shares common boundaries with East-Akim Municipal to the NorthEast, Akwapim North District to the East and South and Suhum-Kraboa-Coaltar District to the East. It covers a land area of 159 square kilometers representing approximately 0.6 percent of the total surface area of the Eastern Region (Fig 3.1). It has 52 major communities with Koforidua as its capital. The Municipality is well served with road net works. Almost all the existing settlements in the Municipality are reached by improved condition of tarred roads and feeder roads. The

Municipality has a road network totaling 72km and road density of 0.62 km.

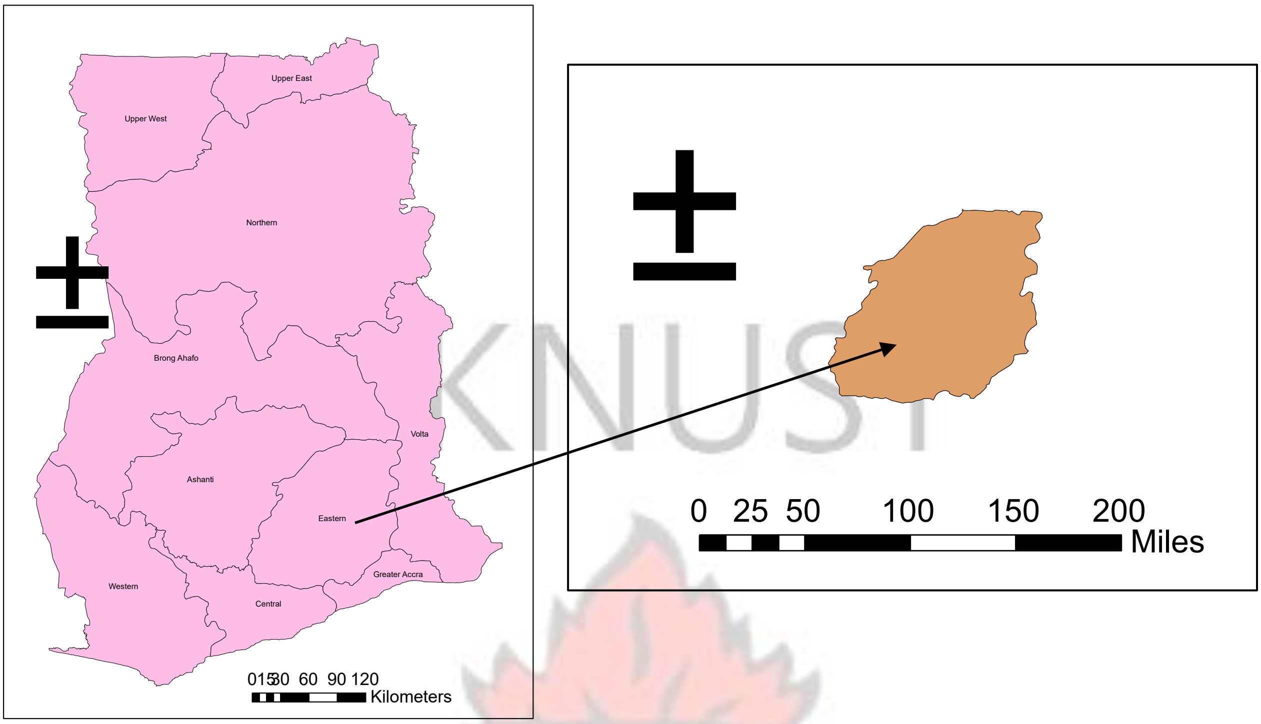


Figure 3.1. Ghana map showing study area

3.2 Climate and Vegetation

The Municipality falls within the semi-deciduous rainforest climatic zone with a bimodal rainy season, with rainfall ranging between, 1200mm and, 1700mm and peaking in May/June and September/October. The dry season, the shortest is experienced between November and February. Humidity and temperature are generally high ranging between 20°C and 32°C. The relatively mildtemperatures make the Municipality a major tourist destination. The vegetation is characterized by tall trees with evergreen undergrowth and rich in economic trees including Odum, Onyina, Kyenkyen, Wawa etc. These species greatly support lumbering and estate development activities. Scattered patches of secondary or broken forest are also present.

3.3 Topography and Drainage

Generally, the land in the municipality ranges between 152 m and 198 m in height above sea level and are undulating in nature. Obuotabiri is the highest area and it is located on the mountain belt along the eastern boundaries of the metropolis. The metropolis is largely drained by the River Densu and its tributaries. The river is dammed at Densuano to provide treated drinking water for the Koforidua Township and its suburbs. There are few waterfalls found at different sections of the Densu River.

3.4 Methods and Procedures

This section presents a description of the hydrologic data used in present study. In addition, a detailed analysis of this data is described to assess the quality as well as the suitability of the data for this study.

3.4.1 Data collected

The data used for this analysis have been provided by the Ghana Meteorological Services Department which has the responsibility of measuring, analyzing and storing meteorological data and forecasting the weather in Ghana. The data consists of annual maximum series (AMS) of rainfall depth over a period of twenty-nine years from 1967 to 2011 for nine (9) laps of time: 12min, 24min, 42min, 1hour, 2hours, 3hours, 6hours, 12hours, and 24hours.

3.4.2 Filling in Missing Data

There were missing data in the data provided by Ghana meteorological Services Department, which had to be filled. Several procedures were followed in order to fill in the missing gaps. Also observing the data, it was seen that the 24min AMS contained less number of missing data and therefore an attempt was made to find the correlation between the 12 min AMS and the rest of the data. When the correlation analysis was performed, it was established that there was a strong correlation between the 42min, 1hr, and 2hrs, 3hrs, 6hrs, 12hrs and 24hrs AMS.

3.4.3 Procedure for selecting the appropriate Probability distribution.

Literature review has shown that, Log Pearson Type III and The Extreme Value type I were the two most appropriate Probability distribution used for IDF curves construction. In order to choose between the two distributions; the following steps were carried out:

- ❖ For each duration, the Gumbel and Log Pearson Type III distributions were fitted to the Annual maximum Series using the Easy Fit soft ware.

Best of fit for each distribution was determined using Anderson Darling, Chisquare and Kolmogorov- Smirnov test-of-goodness-of-fits at 5% significance level for each duration.

- ❖ After the fitting, both distributions were ranked to determine the appropriateness of the fitting.
- ❖ After the analysis, a rank of 1 and 2 were given to the distribution with good fit and less fitting respectively
- ❖ After the analysis, Gumbel distribution gave a better fit than the Log Pearson Type III distribution under the following goodness of fit test; Chi square, Anderson Daring and Kolmogorov-Smirnov for the nine (9) durations.
- ❖ Hence Gumbel distribution was selected for the frequency analysis.

3.4.4 Procedure for Fitting Gumbel distribution to sample data.

The main objective of fitting a statistical distribution to data series is to find out the parameters of the distribution from the sample; and then verify if really the sample are drawn from that statistic.

As it has been hypothesized that extreme rainfall events are drawn from Gumbel distribution, the processes describe below show how the fitting is done .After that a statistical test of goodness of fit is performed to assess the validity of the fitting. When the process succeeds, events of very low probability of occurrence or very high return period can be approximated from the distribution.

Step1: Rank AMS values from highest to lowest; assign a rank m to each value with the highest value having a rank of (one) and the lowest value a rank of n. They constitute the observed data.

Step2: Estimate the exceedance probability. The Weibull and Gringorten formula could be used for the estimation of the cumulative probability distribution. The weibull formula does well and it is exact uniformly distributed population however if the number of observations are limited the weibull formula performs badly especially at the extremes. This is a major drawback for the Weibull formula.

This is overcome by using Gringorten relation proposed for the estimation of the exceedance of the probability data for limited observation. It is given in Equation 3.1 below.

$$P = \frac{m-0.44}{n+0.12} \qquad (3.1)$$

$p = P(X \geq x)$; Note that $p = 1 - F(x)$

$F(x) = P(X < x)$

Step 3: Determine the reduced variable from (p) by the formula

U = -In [- In (1- p)] (3.2) Step 4: Compute the sample mean (μ_s) and standard deviation (σ_s); It can easily be done with Excel program.

Step 5: Find the position parameter (x_0) and the scale parameter (s) of the Gumbel distribution with the following formulae:

$$X_0 = \mu_s - \frac{\mu N}{\sigma N}\sigma_s \qquad (3.3)$$

Step 6: use the formulae below to derive the Gumbel mean μ_G and Standard deviation (σ_G)

$$\mu_G = x_0 + 0.5772 \times s \quad (3.4)$$

$$\sigma_G = 1.2825 \times s \quad (3.5)$$

Step 7: for each rank, the Gumbel variable is obtained by use of the formula

$$X_G = X_0 + u \times s \quad (3.6)$$

They constitute the expected data.

3.5 Procedure for testing the null hypothesis

A test of a hypothesis is defined as a rule that assigns one of the inferences: *"the hypothesis is accepted* "or *"the hypothesis is rejected* "to each foreseeable result of an experiment. The null hypothesis will be H_0:"the observed data are drawn from a Gumbel distribution." In other words the sample is supposed to be extracted from a Gumbel distributed population.

3.5.1 Level of significance

Level of significance is the probability of committing type I error which is the error of rejecting the null hypothesis when it is true.

$$\alpha = \text{prob (rejected } H_0 / H_0 \text{ is true)} \quad (3.7)$$

The test is conducted at a significance level of 5% (α =0.05)

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Application of Procedures and Results

4.1.1 Results of Missing data for various duration

There were missing data in the data provided by Ghana meteorological Services Department, which had to be filled. Several procedures were followed in order to fill in the missing gaps. Also observing the data, it was seen that the 24min AMS contained less number of missing data and therefore an attempt was made to find the correlation between the 12 min AMS and the rest of the data. When the correlation analysis was performed, it was established that there was a strong correlation between the 42min, 1hr, and 2hrs, 3hrs, 6hrs, 12hrs and 24hrs AMS. Table 4.1, 4.2 and Fig.4.1.below indicate the breakdown of the missing data, correlation and scatter diagram.

Table 4.1. Summary of Missing data for various duration.

Duration(hrs)	No. of missing data
0.2	35
0.4	7
0.7	24
1.0	40
2.0	38
3.0	39
6.0	61
12.0	71
24.0	92

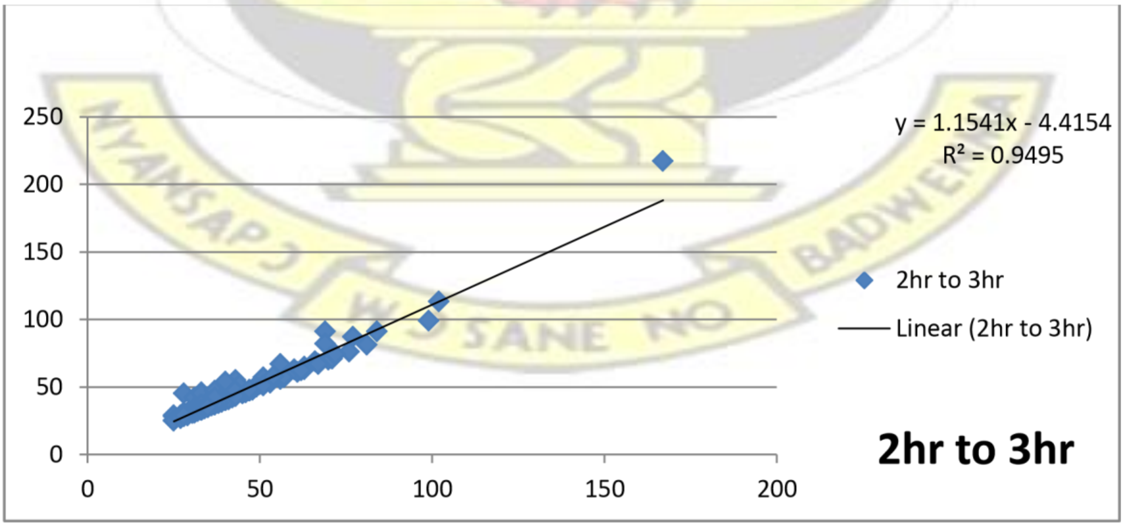


Figure 4.1. Shows scatter diagram various duration

Table 4.2. Presents the summary of Correlation for various time intervals.

	Time interval (hour)								
(hr)	0.2	0.4	0.7	1	2	3	6	12	24
0.2	1.000	0.584	0.533	0.422	0.321	0.262	0.234	0.214	0.166
0.4	0.584	1.000	0.774	0.709	0.497	0.389	0.413	0.399	0.357
0.7	0.533	0.774	1.000	0.902	0.704	0.564	0.492	0.495	0.409
1	0.422	0.709	0.902	1.000	0.810	0.715	0.560	0.602	0.648
2	0.321	0.497	0.704	0.810	1.000	0.974	0.931	0.912	0.884
3	0.262	0.389	0.564	0.715	0.974	1.000	0.971	0.960	0.937
6	0.234	0.413	0.492	0.560	0.931	0.971	1.000	0.986	0.954
12	0.214	0.399	0.495	0.602	0.912	0.960	0.986	1.000	0.985
24	0.166	0.357	0.409	0.648	0.884	0.937	0.954	0.985	1.000

Selecting Appropriate Probability Distribution for 12 min

(0.2) Duration

Fitting the Anderson darling, Chi-square and Kolmogorov-Smirnov tests of goodness of fits to Gumbel and Log Pearson Type III distributions for 12min (0.2hr) duration, the following results were obtained as shown in Table 4.2 below. Gumbel distribution provided a better fit than the Log Pearson Type III distribution under the following goodness of fit test; Chi square, Anderson Daring and KolmogorovSmirnov for the nine (9) durations. Hence Gumbel distribution was selected for the frequency analysis. The results of the fitting for the other durations are found in the appendices.

Table 4.3. Ranking for Gumbel and Log Pearson Type III for the Nine Durations

DURATION	**RANK**					
	K S		AD		**CS**	
	EVI	**LP3**	**EVI**	**LP3**	**EVI**	**LP3**
0.20HR	**1**	**2**	**1**	**2**	**N/A**	**N/A**
0.40HR	**1**	**2**	**1**	**2**	**2**	**1**

0.7HR	**1**	**2**	**1**	**2**	**1**	**2**
1.0HR	**1**	**2**	**1**	**2**	**1**	**2**
2.0HR	**1**	**2**	**1**	**2**	**2**	**1**
3.OHR	**1**	**2**	**1**	**2**	**1**	**2**
6.0HR	**1**	**2**	**1**	**2**	**1**	**N/A**
12HR	**1**	**2**	**1**	**2**	**1**	**1**
24HR	**1**	**2**	**1**	**2**	**1**	**N/A**

KS : Kolmogorov-Smirnov, AD: Anderson Daring CS: Chi square, EVI: Gumbel distribution and LP3: Log Pearson Type III distributions

4.2 Determination of parameters of the Gumbel Distribution

All the computations in the tables below have been done by use of Microsoft Excel program functions. They have been executed according to step 1 through step 7 as described in point 3.16.2. Mean of reduced variable (μ_N) and standard deviation of σ_N are found to be equal to 0.5437 and 1.2344 respectively for N=29.

In the second column of table 4.3,sampled extreme rainfall depth in mm are ordered in descending order. Column four are exceedence probabilities obtained with Gringorten formula.

In column 5, the reduced variable *u* is computed using expression $u = -\ln[-\ln(1-p)]$ (3.2) (3.2) and column 6 of table 4.3 are the expected values. They were directly generated by Gumbel distribution in accordance with formula (3.5). Column 6 of table 3.11 gives the intensities which are obtained by dividing the rainfall depths in column (2) by their respective duration i.e.(0.2hrs).

The mean and standard deviation of the sample and the parameters of the distribution are given above in Table 3.10; they have been derived with respect to formulae (2.4) and (2.5)

Table 4.4. Fitting Gumble distribution to Sample data-0.2Hrs AMS

	0.20 hr Duration				
Year	**Ranked Depth**	**Rank (m)**	**Exceedance Probability (P)**	**Reduced Variable (U)**	**Gumbel Variable (XG)**
2002	35	1	0.019	3.942	54.375
2001	33	2	0.054	2.899	47.252
1971	31	3	0.088	2.386	42.728
1982	28	4	0.122	2.037	38.014
2010	28	5	0.157	1.770	36.702
2004	27	6	0.191	1.552	34.628
1968	25	7.875	0.255	1.221	31.004
1972	25	7.875	0.255	1.221	31.004
1973	25	7.875	0.255	1.221	31.004
1974	25	7.875	0.255	1.221	31.004
1976	25	7.875	0.255	1.221	31.004
1977	25	7.875	0.255	1.221	31.004
1978	25	7.875	0.255	1.221	31.004
1980	25	7.875	0.255	1.221	31.004
2006	24	15	0.500	0.367	25.802
1975	23	16	0.534	0.269	24.321
1979	23	17	0.569	0.173	23.852
2009	22	18	0.603	0.079	22.389
1983	21	19	0.637	-0.014	20.930
1985	21	20	0.672	-0.108	20.470
2003	20	21	0.706	-0.202	19.005
2008	20	22	0.740	-0.299	18.530
1981	19	23	0.775	-0.399	17.038
2005	19	24	0.809	-0.504	16.521
2007	17	25	0.843	-0.617	13.965
2011	17	26	0.878	-0.743	13.349
1969	15	27	0.912	-0.888	10.633
1984	15	28	0.946	-1.074	9.721
1967	4	29	0.981	-1.374	-2.864
Average	**22.8238**			**0.656**	
Standv	**6.06598**			**1.258**	

4.3 Results for testing the null hypothesis ie the data were extracted from the

Gumbel Distribution

To perform the Kolmogorov-Smirnov test, the upper bounds of intervals from Table 4.6 are considered and the respective cumulated frequency (number of sample points smaller than the considered rainfall depth).

In column 5 of Table 4.4, the $F_0(x) = \frac{j}{N}$ values are the ratio of cumulated frequency to 29 (number of sample points). The reduced variable is obtained by $u = \frac{X_0 - x_0}{s}$

The Gumbel cumulative probability distribution prompts theoretical cumulated probabilities

$F_t(x) = F(u) = e^{-e^{-u}}$ (4.1) The last column contains the

Kolmogorov differences $D_n = |F_t(x) - F_0(x)|$.

The highest difference is equal to 0.099 and the critical value for KolmogorovSmirnov given in Appendix I for 5 intervals and a 5% significant level, is 0.099. Since 0.099<0.246 the null hypothesis is accepted at 0.05 significant level.

Both tests confirm that the 29 sample observations are drawn from a Gumbel distribution whose mean is 22.893mm and standard deviation is 6.304mm

Table 4.5. Kolmogorov-Smirnov test (12mins analysis)

1	2	3	4		6	7	8
Interval	Upper limit llboudarr	Ofreq	Cum freq	$F_0(X)$	u		$Dn = \lvert F_t(x) - F_0($
1-5	5	1	1	0.034	**-3.062**	**0**	0.034
6-10	10	0	2	0.034	**-5.920**	**0**	0.034
11-15	15	2	3	0.103	**-1.028**	**0.061**	0.042
16-20	20	6	9	0.310	**-0.011**	**0.364**	0.054
21-25	25	14	23	0.793	**1.005**	**0.694**	**0.099**
26-30	30	3	26	0.896	**1.930**	**0.865**	0.031
31-35	35	3	29	1.00	**2.948**	**0.949**	0.051

0.099 <0.246, ***null hypothesis is accepted at 0.05 level of significance***

Tables 4.6 and 4.7 below show the tests- of- goodness-of-fit done on the measured data i.e. using chi-square test. After the analysis eight of the durations were confirmed to be drawn from a Gumbel distribution whiles one of them was not with four degree of freedom. Using a 5% significance level, if the value is less or equal to 5% significance level than we assume that the observation is drawn from a gumble distribution. From Appendix 29, we read that for 4 degrees of freedom and 0.050 significance, the χ^2 $8.42 \leq 9.488$, the hypothesis that the annual data is drawn from a Gumbel distribution is accepted.

Table 4.6. Observed frequency; E: Expected frequency

RANGE (mm)	O freq	E freq
0-5	0	1
5-10	0	1
10-15	1	0
15-20	1	1
20-25	1	2
25-30	2	3
30-35	7	3
35-40	6	3
40-45	6	3
45-50	2	2
50-55	1	2
55-60	0	3
60-65	0	0
65-70	1	2
70-75	1	1
75-80	0	0
80-85	0	0

85-90	0	0
90-95	0	1
95-100	0	0
100-105	0	0
105-110	0	1
	SUM =29	SUM = 29

O; Observed frequency; E: Expected frequency

Table 4.7. Chi –square

test (0.4 hr analysis)					
RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-30	5	8	-3	9	1.8
30-35	7	3	4	16	2.285714286
35-40	6	3	3	9	1.5
40-45	6	3	3	9	1.5
45-60	3	5	-2	4	1.333333333
60-100	2	5	-3	9	0
>100	0	2	-2	4	0
	sum = 29	sum = 29			sum=8.42

Table 4.8. Rainfall intensities for all the duration

T	K_T	X_T
5	0.8704	28.38
10	1.5478	32.65
15	1.93	35.059
20	2.226	36.925
25	2.4032	38.042
50	3.0384	42.047
100	3.6682	46.017

4.4 Determination of the IDF curves

Expected Annual Rainfall depth for all the return periods is obtained with the following formula

$X_T = \mu_G + K_T \text{ X } \sigma_G$ (Chow, 1964) (4.2)

Where μ_G and σ_G are Gumbel distribution‟s mean and standard deviation; and K_T is a frequency factor.

$$K_T = -\frac{\sqrt{6}}{\pi}\{0.577216 + \text{In}\,[\,\text{In}\,(\frac{T}{T-1})]\,\} \quad (4.\,3)$$

For return period equal to one year, the formula of K_T does not stand and the following formula is used.

$$K_T = -\frac{\sqrt{6}}{\pi} \text{ X } [\,0.5772 - \text{InT} + \frac{1}{2\,X\,T} + \frac{1}{24\,X\,T^2} + \frac{1}{8\,X\,T^3}\,] \quad (4.\,4)$$

For T = 5, K_T = 0.8704 and the corresponding rainfall depth is equal to

X_T = 28.38 mm in the table above some estimates are provided.

Similar computations have been done for the other durations and they are found in the appendices.

The Intensity-Duration-Frequency estimates are deduced from Table 4.8. by division of Expected rainfall depth (mm) with their respective duration in hour (hr). They are represented in Table 4.9 below.

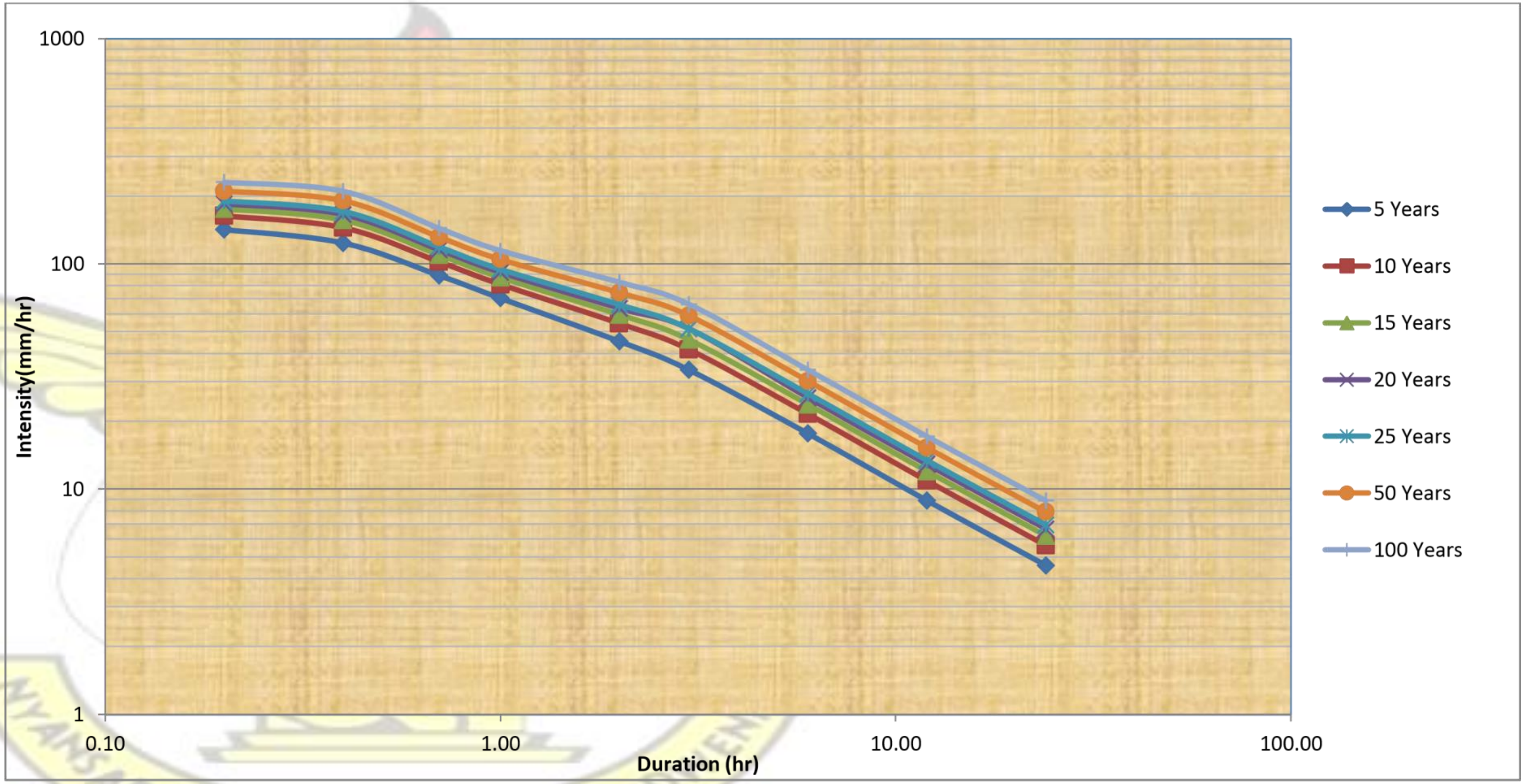
Table 4.9. Intensity-Duration-Frequency estimates (complete table)

	Return Period						
Duration	5	10	15	20	25	50	100
0.2	141.90	163.25	175.30	184.63	190.21	210.24	230.09
0.4	123.80	144.70	156.48	165.61	171.08	190.67	210.10
0.7	88.77	102.10	109.62	115.44	118.93	131.42	143.81
1	70.37	81.06	87.10	91.77	94.57	104.60	114.54

2	45.26	54.37	59.52	63.50	65.88	74.44	82.91
3	33.79	41.63	46.05	51.53	51.53	58.88	66.17
6	17.64	21.56	23.77	25.48	26.51	30.18	33.82
12	8.89	10.88	12.01	12.88	13.40	15.28	17.13
24	4.58	5.62	6.21	6.66	6.93	7.91	8.87

Rainfall Intensities are in mm/hr

Rainfall estimates in mm and their intensities in mm/hr for various return periods were analyzed using Gumbel distribution. Table 4.9 above presents maximum rainfall intensities at durations of 12min, 24min, 42min, 1hr, 2hrs, 3hrs, 6hrs, 12hrs and 24hrs at return periods of 5,10,15,20,25,50,and100yr.The intensity duration frequency curves are obtained by plotting the rainfall intensity values against corresponding durations for different return periods. The IDF curves for Koforidua are shown in Figs 4.2. and 4.3 below. From Table 4.9 above, it shows that intensities are increasing with increase in return period and decrease with duration in all the return periods. From the results it appears that Rainfall intensities rise in parallel with the rainfall return periods and also for the same return period, high intensities are related to short durations.



1000
100
10
1
0.10
1.00
10.00
100.00
Intensity(mm/hr)
Duration (hr)
5 Years
10 Years
15 Years
20 Years
25 Years
50 Years
100 Years

Figure 4.2. Shows log - logarithms

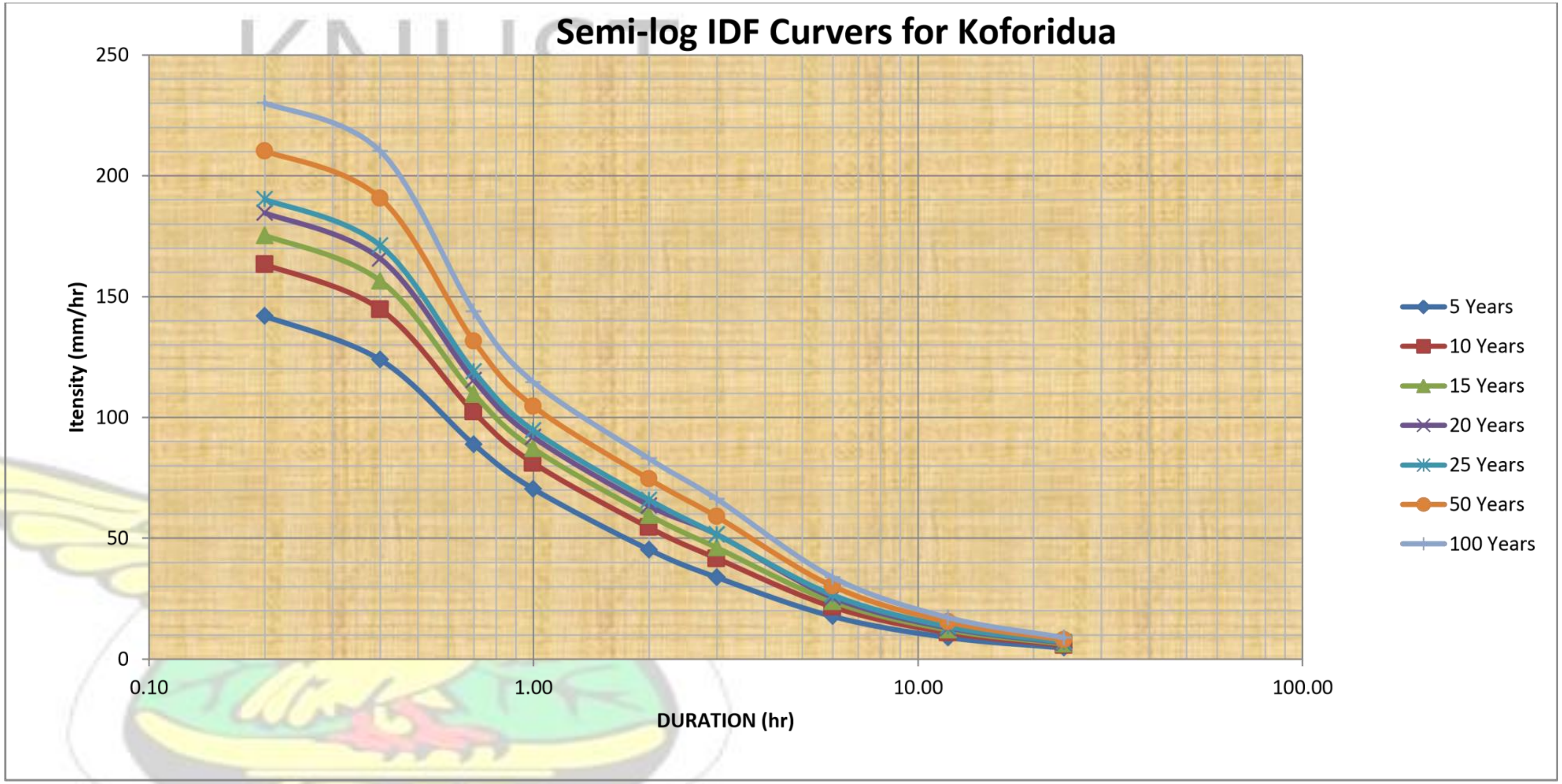


Figure 4.3. Shows Semi - logarithms

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The study was conducted for the formulation and construction of IDF curves using data from recorded stations. Missing gabs in the data collected were filled using correlation analysis. Literature review presented the, Log Pearson Type III and The Extreme Value type I were the two most appropriate probability distribution used for IDF curves construction. By using easy fit software, Gumbel Extreme type I was found to be the best distribution for the data set. The Intensity- Duration-FrequencyCurves obtained for the study area has the general characteristic form of IntensityDuration-Frequency-Curves.

5.2 Recommendations.

It is recommend that:

- Meteorological Services Department must strengthen their data collection processing, and storage facilities to ensure easy access and retrieval.
- All hydraulic infrastructure works from now shouild be designed using the IDF curves generated for Koforidua.
- Due to the variability in climate condition, it is recommended that IDF curves be prepared for all the major cities in Ghana.

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APPENDICES

Appendix 1 Critical values of Kolmogorov-Smirnov test.

Sample size (n)	Critical differences D□(n)				
	□ = .20	□ = .15	□ = .10	□ = .05	□ = .01
1	.900	.925	.950	.975	.995
2	.684	.726	.776	.842	.929
3	.565	.597	.642	.708	.828
4	.494	.525	.564	.624	.733

Appendix 2 12 Minute AMS Sample and distribution parameters

5	.446	.474	.510	.565	.669
6	.410	.436	.470	.521	.618
7	.381	.405	.438	.486	.577
8	.358	.381	.411	.457	.543
9	.339	.360	.388	.432	.514
10	.322	.342	.368	.410	.490
11	.307	.326	.352	.391	.468
12	.295	.313	.338	.375	.450
13	.284	.302	.325	.361	.433
14	.274	.292	.314	.349	.418
15	.266	.283	.304	.338	.404
16	.258	.274	.295	.328	.392
17	.250	.266	.286	.318	.381
18	.244	.259	.278	.309	.371
19	.237	.252	.272	.301	.363
20	.231	.246	.264	.294	.356
25	.210	.220	.240	.270	.320
30	.190	.200	.220	.240	.290
35	.180	.190	.210	.230	.270
> 35	1.07 / $\sqrt{n}$	1.14 / $\sqrt{n}$	1.22 / $\sqrt{n}$	1.36 / $\sqrt{n}$	1.63 / $\sqrt{n}$

Appendix 3 12 minute (0.2 hrs) AMS analysis

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (μs)	22.824
Sample standard deviation (σ)	6.066
Position Parameter (X)	20.056
Scale Parameter (S)	4.916
Gumbel Mean (μ_G)	22.893
Gumbel Standard deviation (σG)	6.304
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.234

Appendix 4 24 Minute AMS Sample and distribution parameters

0.20 hr Duration					
Year	**Ranked Depth**	**Rank (m)**	**Exceedence Probability (P)**	**Reduced Variable (U)**	**Gumbel Variable (XG)**
2002	35	1	0.019	3.942	54.375
2001	33	2	0.054	2.899	47.252
1971	31	3	0.088	2.386	42.728
1982	28	4	0.122	2.037	38.014
2010	28	5	0.157	1.770	36.702
2004	27	6	0.191	1.552	34.628
1968	25	7.875	0.255	1.221	31.004
1972	25	7.875	0.255	1.221	31.004
1973	25	7.875	0.255	1.221	31.004
1974	25	7.875	0.255	1.221	31.004
1976	25	7.875	0.255	1.221	31.004
1977	25	7.875	0.255	1.221	31.004
1978	25	7.875	0.255	1.221	31.004
1980	25	7.875	0.255	1.221	31.004
2006	24	15	0.500	0.367	25.802
1975	23	16.5	0.552	0.221	24.085
1979	23	16.5	0.552	0.221	24.085
2009	22	18	0.603	0.079	22.389
1983	21	19.5	0.655	-0.061	20.700
1985	21	19.5	0.655	-0.061	20.700
2003	20	21.5	0.723	-0.250	18.769
2008	20	21.5	0.723	-0.250	18.769
1981	19	23.5	0.792	-0.451	16.784
2005	19	23.5	0.792	-0.451	16.784
2007	17	25.5	0.861	-0.678	13.666
2011	17	25.5	0.861	-0.678	13.666

Appen minute (hrs) AMS analysis

1969	15	27.5	0.929	-0.974	10.212
1984	15	27.5	0.929	-0.974	10.212
1967	4	29	0.981	-1.374	-2.864
Average	**22.8238**			**0.657**	
Standv	**6.06598**			**1.257**	

Appendix 5 24 0.4

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (μs)	38.648
Sample standard deviation (σ)	11.871
Position Parameter (X)	33.231
Scale Parameter (S)	9.620
Gumbel Mean (μ_G)	38.783
Gumbel Standard deviation (σG)	12.337
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.234

Appendix 6 0.7 Minute AMS Sample and distribution parameters

0.4hr Duration					
Year	**Ranked depth**	**Ranke (M)**	**Exceedence Probability(P)**	**Reduced variable (U)**	**Gumbel variable(XG)**
2004	72	1	0.019	3.942	109.917
1968	64	2	0.054	2.899	91.891
1973	51	3	0.088	2.386	73.951
1982	50	4	0.122	2.037	69.597
1977	50	5	0.157	1.770	67.029
1976	45	6	0.191	1.552	59.928
2010	44	7.5	0.242	1.281	56.326
2002	44	7.5	0.242	1.281	56.042
2006	43	9.5	0.311	0.987	52.495
1971	43	9.5	0.311	0.987	52.495
1978	42	11	0.363	0.798	49.673
2005	40	12	0.397	0.682	46.557
1981	38	13.5	0.448	0.519	42.993
1974	38	13.5	0.448	0.519	42.993
1983	37	15	0.500	0.367	40.526
2001	36	16.5	0.552	0.221	38.124
1975	36	16.5	0.552	0.221	38.124
2009	35	18	0.603	0.079	35.762
2007	35	19	0.637	-0.014	34.678
2011	34	20.5	0.689	-0.155	32.510

minute (hrs) AMS analysis

1980	34	20.5	0.689	-0.155	32.510
2003	32	22	0.740	-0.299	29.123
1979	31	23.5	0.792	-0.451	26.662
1972	31	20.5	0.689	-0.155	29.510
1985	30	25	0.843	-0.617	24.061
2008	29	26	0.878	-0.743	21.855
1969	25	27	0.912	-0.888	16.453
1984	19	28	0.946	-1.074	8.669
1967	13	29	0.981	-1.374	0.042
Average	**38.648**			**0.572**	
Standand	**11.87088**			**1.226**	

dix 7 24 0.7

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (μs)	50.001
Sample standard deviation (σ)	13.251
Position Parameter (X)	43.956
Scale Parameter (S)	10.738
Gumbel Mean (μ_G)	50.154
Gumbel Standard deviation (σG)	13.771
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.234

Appendix 8 1 hour AMS Sample and distribution parameters

	Duration 0.7hr				
Year	**Ranked Depth**	**ranke (M)**	**Exceedence Probability(P)**	**Reduced Variable (U)**	**Gumble Variable(XG)**
2004	77	1	0.019	3.942	119.324
1968	71	2	0.054	2.899	102.133
1977	70	3	0.088	2.386	95.618
1971	69	4	0.122	2.037	90.875
1973	66	5	0.157	1.770	85.008
1976	64	6	0.191	1.552	80.663
2006	60	7	0.225	1.366	74.663
2005	57	8	0.260	1.202	69.907
2010	56	9	0.294	1.055	67.332
1982	55	10	0.328	0.921	64.895
2002	54	11	0.363	0.798	62.564
2001	54	12	0.397	0.682	61.319
1972	53	13	0.431	0.572	59.141

Appen minute (hrs) AMS analysis

1981	51	14	0.466	0.467	56.017
2011	47	15	0.500	0.367	50.936
2009	46	16	0.534	0.269	48.886
2007	43	17.66	0.591	0.111	44.489
1983	43	17.66	0.591	0.111	44.193
1980	43	17.66	0.591	0.111	44.193
1974	43	20	0.672	-0.108	41.842
1978	42	21	0.706	-0.202	39.827
2003	41	22.5	0.758	-0.349	37.258
1975	41	22.5	0.758	-0.349	37.258
1979	40	24	0.809	-0.504	34.585
1985	39	25	0.843	-0.617	32.370
1969	38	26	0.878	-0.743	30.025
2008	36	27	0.912	-0.888	26.460
1984	31	28	0.946	-1.074	19.469
1967	20	29	0.981	-1.374	4.974
Average	**50.0009**			**0.566**	
Standv	**13.2508**			**1.232**	

Appen

dix 9 1 hour (1 hr) AMS analysis

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (μs)	56.474
Sample standard deviation (σ)	15.192
Position Parameter (X)	49.520
Scale Parameter (S)	12.311
Gumbel Mean (μ_G)	56.626
Gumbel Standard deviation (σG)	15.789
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.212

Appendix 10 2 hour AMS Sample and distribution parameters

1hr Duration					
	Ranked	**Rank**	**Excceedence**	**Reduced**	**Gumble**
Year	**Depth**	**(M)**	**Probability(P)**	**Variable(U)**	**Variable(XG)**
2004	101	1	0.019	3.942	149.526
	76	2	0.054	2.899	111.695
1968	74	3	0.088	2.386	103.372
2006	73	4	0.122	2.037	98.080
1971	71	5.5	0.174	1.656	91.389
1976	71	5.5	0.174	1.656	91.389
1977	70	7	0.225	1.366	86.812
2010	66	8	0.260	1.202	80.799
1974	64	9	0.294	1.055	76.993
1981	59	10.5	0.345	0.858	69.568
2002	59	10.5	0.345	0.858	69.568
2005	58	12	0.397	0.682	66.392
1982	57	13.5	0.448	0.519	63.390
2001	57	13.5	0.448	0.519	63.390
1972	56	15	0.500	0.367	60.512
1980	53	16	0.534	0.269	56.309
1975	52	17	0.569	0.173	54.133
2009	52	18	0.603	0.079	52.975
2003	50	19	0.637	-0.014	49.825
2008	50	20	0.672	-0.108	48.673
2011	48	21	0.706	-0.202	45.508
2007	48	22	0.740	-0.299	43.910
1979	47	23	0.775	-0.399	42.087
1978	42	24	0.809	-0.504	35.791

Appen hours (hrs) AMS analysis

1969	41	25	0.843	-0.617	33.399
1983	40	26.66	0.900	-0.836	29.710
1984	40	26.66	0.900	-0.836	29.710
1985	40	26.66	0.900	-0.836	29.710
1967	23	29	0.981	-1.374	6.229
Average	**56.4737**			**0.569**	
Standv	**15.1924**			**1.203**	

dix 11 2 2

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (μs)	66.796
Sample standard deviation (σ)	25.894
Position Parameter (X)	54.982
Scale Parameter (S)	20.984
Gumbel Mean (μ_G)	67.093
Gumbel Standard deviation (σG)	26.912
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.234

Appendix 12 3 hour AMS Sample and distribution parameters

Year	2hr Duration Ranked Depth	Ranke (M)	Exceedence Probability(P)	Reduced Variable(U)	Gumbel Variable(XG)
2001	167	1	0.019	3.942	249.709
2004	102	2	0.054	2.899	227.839
1971	99	3	0.088	2.386	152.062
1973	84	4	0.122	2.037	141.748
1968	83	5	0.157	1.770	121.145
1974	81	6	0.191	1.552	115.493
2006	77	7	0.225	1.366	109.654
1979	72	8	0.260	1.202	102.223
1976	71	9.5	0.311	0.987	92.711
1977	71	9.5	0.311	0.987	91.711
1975	69	11	0.363	0.798	87.736
2002	67	12.5	0.414	0.626	82.137
2010	67	12.5	0.414	0.626	80.137
1981	66	14	0.466	0.467	76.805
1983	63	15	0.500	0.367	73.691
2005	62	16.5	0.552	0.221	67.633
2008	62	16.5	0.552	0.221	66.633

Appen hours (hrs) AMS analysis

1982	57	18.5	0.620	0.032	62.681
2003	57	18.5	0.620	0.032	57.681
1972	56	20.5	0.689	-0.155	53.749
2009	56	20.5	0.689	-0.155	52.749
2011	53	22.5	0.758	-0.349	48.687
1980	53	22.5	0.758	-0.349	46.001
2007	53	24	0.809	-0.504	42.418
1969	46	25	0.843	-0.617	39.894
1984	43	26	0.878	-0.743	30.415
1985	40	27	0.912	-0.888	24.356
1978	35	28	0.946	-1.074	17.466
1967	25	29	0.981	-1.374	6.168
Average	**66.7964**			**0.562**	
Standv	**25.8941**			**1.233**	

dix 13 3 3

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (µs)	71.231
Sample standard deviation (σ)	33.398
Position Parameter (X)	55.993
Scale Parameter (S)	27.069
Gumbel Mean (μ_G)	71.161
Gumbel Standard deviation (σG)	34.716
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.234

Appendix 14 6 hour AMS Sample and distribution parameters

	3hr Duration				
	Ranked	**Ranke**	**Exceedence**	**Reduced**	**Gumble**
Year	**Depth**	**(M)**	**Probability(p)**	**Variable(U)**	**Variable(XG)**
2001	217	1	0.019	3.942	323.694
2004	113	2	0.054	2.899	191.482
1971	99	3	0.088	2.386	163.580
1973	91	4	0.122	2.037	146.144
1974	91	5	0.157	1.770	138.916
2006	87	6	0.191	1.552	129.005
1975	82	7	0.225	1.366	118.963
1979	74	8	0.260	1.202	106.538
1976	71	9.5	0.311	0.987	97.717

Appen hours (hrs) AMS analysis

1977	71	9.5	0.311	0.987	97.717
1981	69	11	0.363	0.798	90.590
2002	67	12.66	0.420	0.609	83.474
2009	67	12.66	0.420	0.609	83.474
2010	67	12.66	0.420	0.609	83.474
1983	65	15	0.500	0.367	74.921
2008	63	16	0.534	0.269	70.276
2005	62	17	0.569	0.173	66.690
1968	58	18.5	0.620	0.032	58.878
2003	58	18.5	0.620	0.032	58.878
2011	57	20.66	0.694	-0.170	52.511
1982	57	20.66	0.694	-0.170	52.397
2007	57	20.66	0.694	-0.170	51.970
1972	56	23	0.775	-0.399	45.198
1984	55	24	0.809	-0.504	41.349
1980	53	25	0.843	-0.617	36.288
1985	50	26	0.878	-0.743	29.895
1969	46	27	0.912	-0.888	21.950
1978	35	28	0.946	-1.074	5.931
1967	28	29	0.981	-1.374	-9.194
Average	**71.2306**			**0.569**	
Standv	**33.3983**			**1.231**	

dix 15 6 6

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (μs)	75.233
Sample standard deviation (σ)	33.398
Position Parameter (X)	60.000
Scale Parameter (S)	27.064
Gumbel Mean (μ_G)	75.621
Gumbel Standard deviation (σG)	34.709
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.234

Appendix 16 12 hour AMS Sample and distribution parameters

6hr Duration					
	Ranked	**Ranke**	**Exceedence**	**Reduced**	**Gumble**
Year	**Depth**	**(M)**	**Probability(P)**	**Variable(U)**	**Variable(XG)**
2001	219	1	0.019	3.942	325.674

Appen hours (hrs) AMS analysis

2004	113	2	0.054	2.899	191.468
1974	109	3	0.088	2.386	173.568
1971	99	4	0.122	2.037	154.134
1973	94	5	0.157	1.770	141.908
1975	93	6	0.191	1.552	134.997
1979	91	7	0.225	1.366	127.957
2006	87	8	0.260	1.202	119.532
1982	75	9	0.294	1.055	103.561
1976	71	10	0.328	0.921	95.938
1977	71	11	0.363	0.798	92.586
1981	70	12	0.397	0.682	88.447
2002	67	13	0.431	0.572	82.479
2009	67	14	0.466	0.467	79.646
2010	67	15	0.500	0.367	76.919
2003	66	16	0.534	0.269	73.275
2008	66	17	0.569	0.173	70.369
1983	65	18	0.603	0.079	67.143
1968	64	19	0.637	-0.014	63.614
2005	64	20	0.672	-0.108	61.082
2011	60	21	0.706	-0.202	54.337
2007	59	22	0.740	-0.299	51.177
1972	56	23	0.775	-0.399	45.200
1984	56	24	0.809	-0.504	42.352
1980	53	25	0.843	-0.617	36.291
1985	50	26	0.878	-0.743	29.899
1978	49	27	0.912	-0.888	24.954
1969	48	28	0.946	-1.074	18.936
1967	33	29	0.981	-1.374	-4.187
Average	**75.2333**	**1.234**	**0.563**	**Standv**	**33.3982**

Appen

dix 17 12 hours (12 hrs) AMS analysis

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (μs)	75.500
Sample standard deviation (σ)	34.012
Position Parameter (X)	59.982
Scale Parameter (S)	27.562
Gumbel Mean (μ_G)	75.891
Gumbel Standard deviation (σG)	35.352
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.234

Appendix 18 24 hour AMS Sample and distribution parameters

12hr Dration					
Year	**Ranked Depth**	**Ranke (M)**	**Exceedence Probability(P)**	**Reduced Variable(U)**	**Gumble Variable(XG)**
2001	219	1	0.019	3.942	327.638
1974	122	2	0.054	2.899	201.912
2004	114	3	0.088	2.386	179.757
1971	99	4	0.122	2.037	155.149
1973	94	5	0.157	1.770	142.790
1975	93	6	0.191	1.552	135.770
1979	92	7	0.225	1.366	129.637
2006	87	8	0.260	1.202	120.131
1981	72	9	0.294	1.055	101.087
1976	71	10	0.328	0.921	96.397
1977	71	11	0.363	0.798	92.983
1968	69	12	0.397	0.682	87.787
2002	67	13	0.431	0.572	82.764
2009	67	14	0.466	0.467	79.879
2010	67	15	0.500	0.367	77.102
2003	66	16	0.534	0.269	73.409
1983	65	17	0.569	0.173	69.776
2005	64	18	0.603	0.079	66.182
2008	63	19	0.637	-0.014	62.607
2011	61	20	0.672	-0.108	57.587
2007	60	21	0.706	-0.202	54.439
1984	59	22	0.740	-0.299	50.758
1982	57	23	0.775	-0.399	46.001
1972	56	24	0.809	-0.504	42.100
1980	53	25	0.843	-0.617	35.983

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1978	50	26	0.878	-0.743	29.529
1985	50	27	0.912	-0.888	25.512
1969	48	28	0.946	-1.074	18.401
1967	34	29	0.981	-1.374	-3.932
Average	**75.5005**			**0.563**	
Standv	**34.012**			**1.234**	

dix 19 24 hours (12 hrs) AMS analysis

Analyzed Gumbel distribution Parameters	
Description of parameter	**Value (mm)**
Sample mean (μs)	77.586
Sample standard deviation (σ)	35.3829
Position Parameter (X)	61.44
Scale Parameter (S)	28.673
Gumbel Mean (μ_G)	77.99
Gumbel Standard deviation (σG)	36.773
Mean of reduced variable (μ_R)	0.563
Standard deviation of reduced variable	1.234

Appendix 20 24 hour AMS Sample and distribution parameters

24h Duration					
Year	**Ranked Depth**	**Ranke (M)**	**Excceedence Probabilty(P)**	**Reduced Variable(u)**	**Gumble Variable(XG)**
2001	219	1	0.019	3.942	332.016
1974	142	2	0.054	2.899	225.133
2004	127	3	0.088	2.386	195.407
1971	101	4	0.122	2.037	159.803
1973	94	5	0.157	1.770	144.756
1975	93	6	0.191	1.552	137.494
1979	92	7	0.225	1.366	131.154
2006	87	8	0.260	1.202	121.466
1982	75	9	0.294	1.055	105.259
1981	72	10	0.328	0.921	98.421
1976	71	11	0.363	0.798	93.869
1977	71	12	0.397	0.682	90.544
2002	71	13	0.431	0.572	87.399
1968	69	14	0.466	0.467	82.398
2003	67	15	0.500	0.367	77.509
2009	67	16	0.534	0.269	74.707
2010	67	17	0.569	0.173	71.968

Appen

1983	65	18	0.603	0.079	67.270
2005	64	19	0.637	-0.014	63.591
2008	63	20	0.672	-0.108	59.909
2011	62	21	0.706	-0.202	56.045
2007	61	22	0.740	-0.299	52.723
1984	59	23	0.775	-0.399	47.558
1972	56	24	0.809	-0.504	41.540
1980	53	25	0.843	-0.617	35.297
1969	51	26	0.878	-0.743	29.704
1978	51	27	0.912	-0.888	25.519
1985	50	28	0.946	-1.074	19.208
1967	34	29	0.981	-1.374	-4.928
Average	**77.7586**			**0.563**	
Standv	**35.3829**			**1.234**	

dix 20 test 0.2 Hours(12mins) AMS

Kolmogorov Test							
Range	**Upper boundare**	**OFΣ**	**CUMULATIVE**	**Fo(X)**	**REDURED VARIABLE**	**Ft(U)**	**I Ft(u) - Fo(X) I**
1-5	**5**	**1**	**1**	**0.034**	**-3.062**	**0**	0.034
6-10	**10**	**0**	**1**	**0.034**	**-5.920**	**0**	0.034
11-15	**15**	**2**	**3**	**0.103**	**-1.028**	**0.061**	0.042
16-20	**20**	**6**	**9**	**0.310**	**-0.011**	**0.364**	0.054
21-25	**25**	**14**	**23**	**0.793**	**1.005**	**0.694**	**0.099**
26-30	**30**	**3**	**26**	**0.896**	**1.930**	**0.865**	0.031
31-35	**35**	**3**	**29**	**1.000**	**2.948**	**0.949**	0.051
0.099 < 0.246 null hypothesis is accepted at 0.05 level significance							

Appendix 21 Kolmogorov-Smirnov test 0.4 Hours(0.4 hr) AMS

Kolmogorov Test							
Range	**Upper boundare**	**OFΣ**	**CUMULATIVE**	**Fo(X)**	**REDURED VARIABLE**	**Ft(U)**	**I Ft(u) - Fo(X) I**
10-15	**15**	**1**	**1**	**0.034**	**-1.895**	**0.001**	0.033
16-20	**20**	**1**	**2**	**0.069**	**-1.375**	**0.019**	0.050
21-25	**25**	**1**	**3**	**0.103**	**-0.855**	**0.095**	0.008
26-30	**30**	**2**	**5**	**0.172**	**-0.335**	**0.247**	0.075
31-35	**35**	**7**	**12**	**0.414**	**0.183**	**0.435**	0.021
36-40	**40**	**6**	**18**	**0.621**	**0.704**	**0.610**	0.011

Appen *Kolmogorov-Smirnov*

41-45	**45**	**6**	**24**	**0.828**	**1.223**	**0.745**	0.083
46-50	**50**	**2**	**26**	**0.897**	**2.262**	**0.901**	0.005
51- 55	**55**	**1**	**27**	**0.931**	**2.262**	**0.901**	0.030
56-60	**60**	**0**	**27**	**0.931**	**2.782**	**0.940**	0.009
61-65	**65**	**1**	**28**	**0.966**	**3.302**	**0.964**	0.002
66-70	**70**	**0**	**28**	**0.966**	**3.822**	**0.978**	0.013
71-75	**75**	**1**	**29**	**1.000**	**4.341**	**0.987**	0.013
	0.083 < 0.246 null hypothesis is accepted at 0.05 level significance						

dix 22 Kolmogorov-Smirnov test 0.7 Hours(0.7mins) AMS

Kolmogorov Test							
Range	**Upper boundare**	**OFΣ**	**CUMULATIVE**	**Fo(X)**	**REDURED VARIABLE**	**Ft(U)**	**I Ft(u) - Fo(X) I**
20-25	**25**	**1**	**1**	**0.034**	**-1.765**	**0.003**	0.032
26-30	**30**	**0**	**1**	**0.034**	**-1.300**	**0.026**	0.009
31-35	**35**	**1**	**2**	**0.069**	**-0.834**	**0.100**	0.031
36-40	**40**	**4**	**6**	**0.207**	**-0.368**	**0.236**	0.029
41-45	**45**	**7**	**13**	**0.448**	**0.097**	**0.404**	0.045
46-50	**50**	**2**	**15**	**0.517**	**0.563**	**0.566**	**0.049**
51-55	**55**	**5**	**20**	**0.690**	**1.028**	**0.699**	0.010
56-60	**60**	**3**	**23**	**0.793**	**1.494**	**0.799**	0.006
61-65	**65**	**2**	**25**	**0.862**	**1.960**	**0.869**	0.007
66-70	**70**	**2**	**27**	**0.931**	**2.425**	**0.915**	0.016
71-75	**75**	**1**	**28**	**0.966**	**2.891**	**0.946**	0.020
76-80	**80**	**1**	**29**	**1.000**	**3.357**	**0.966**	0.034
	0.049 < 0.246 null hypothesis is accepted at 0.05 level significance						

Appendix 23 Kolmogorov-Smirnov test 1Hour(1hr) AMS

Kolmogorov Test							
Range	**Upper boundare**	**OFΣ**	**CUMULATIVE**	**Fo(X)**	**REDURED VARIABLE**	**Ft(U)**	**I Ft(u) - Fo(X) I**
20-25	**25**	**1**	**1**	**0.034**	**-1.992**	**0.001**	0.034
26-30	**30**	**0**	**1**	**0.034**	**-1.586**	**0.008**	0.027
31-35	**35**	**0**	**1**	**0.034**	**-1.179**	**0.039**	0.004
36-40	**40**	**3**	**4**	**0.138**	**-0.773**	**0.115**	0.023

Appen

41-45	**45**	**2**	**6**	**0.207**	**-0.367**	**0.236**	0.029
46-50	**50**	**5**	**11**	**0.379**	**0.039**	**0.382**	0.003
51-55	**55**	**3**	**14**	**0.483**	**0.445**	**0.527**	0.044
56-60	**60**	**6**	**20**	**0.690**	**0.851**	**0.653**	0.037
61-65	**65**	**1**	**21**	**0.724**	**1.257**	**0.752**	0.028
66-70	**70**	**2**	**23**	**0.793**	**1.664**	**0.827**	0.034
71-75	**75**	**4**	**27**	**0.931**	**2.070**	**0.881**	**0.050**
76-80	**80**	**1**	**28**	**0.966**	**2.476**	**0.919**	0.046
81-85	**85**	**0**	**28**	**0.966**	**2.882**	**0.946**	0.020
86-90	**90**	**0**	**28**	**0.966**	**3.288**	**0.963**	0.002
91-95	**95**	**0**	**28**	**0.966**	**3.694**	**0.975**	0.010
96-100	**100**	**0**	**28**	**0.966**	**4.100**	**0.984**	0.018
101-105	**105**	**1**	**29**	**1.000**	**4.507**	**0.989**	0.011
106-110	**110**	**0**	**29**	**1.000**	**4.913**	**0.993**	0.007
	0.050 < 0.246 null hypothesis is accepted at 0.05 level significance						

Appen Kolmogorov-Smirnov rs(2 hrs) AMS
dix 24 test 2 Hou

Kolmogorov Test								
Range	**Upper boundare**	**OFΣ**	**CUMULATIVE**	**Fo(X)**	**REDURED VARIABLE**	**Ft(U)**	**I Ft(u) - Fo(X) I**
20-25	25	1	1	0.034	-1.429	0.015	0.019
26-30	30	0	1	0.034	-1.191	0.037	0.003
31-35	35	1	2	0.069	-0.952	0.075	0.006
36-0	40	1	3	0.103	-0.714	0.130	0.026
41-45	45	1	4	0.138	-0.476	0.200	0.062
46-50	50	1	5	0.172	-0.237	0.281	0.109
51-55	55	3	8	0.276	0.001	0.368	0.092
56-60	60	4	12	0.414	0.239	0.455	0.041
61-65	65	3	15	0.517	0.477	0.538	0.020
66-70	70	4	19	0.655	0.716	0.613	0.042
71-75	75	3	22	0.759	0.954	0.680	0.078
76-80	80	1	23	0.793	1.192	0.738	0.055
81-85	85	3	26	0.897	1.431	0.787	0.109
86-90	90	0	26	0.897	1.669	0.828	0.068
91-95	95	0	26	0.897	1.907	0.862	0.035
96-100	100	1	27	0.931	2.145	0.890	0.041
101-105	105	1	28	0.966	2.384	0.912	0.054
106-110	110	0	28	0.966	2.622	0.930	0.036
111-115	115	0	28	0.966	2.860	0.944	0.021
116-120	120	0	28	0.966	3.098	0.956	0.010
121-125	125	0	28	0.966	3.337	0.965	0.000
126-130	130	0	28	0.966	3.575	0.972	0.007
131-135	135	0	28	0.966	3.813	0.978	0.013
136-140	140	0	28	0.966	4.052	0.983	0.017
141-145	145	0	28	0.966	4.290	0.986	0.021
146-150	150	0	28	0.966	4.528	0.989	0.024
151-155	155	0	28	0.966	4.766	0.992	0.026
156-160	160	0	28	0.966	5.005	0.993	0.028
161-165	165	0	28	0.966	5.243	0.995	0.029
166-170	170	1	29	1.000	5.481	0.996	0.004
		29					
	0.109 < 0.246 null hypothesis is accepted at 0.05 level significance						

Appen *rs(2 hrs) AMS*

dix 25 Kolmogorov-Smirnov test 3 Hou

Kolmogorov Test							
Range	**Upper boundare**	**OFΣ**	**CUMULATIVE**	**Fo(X)**	**REDURED VARIABLE**	**Ft(U)**	**I Ft(u) - Fo(X) I**
26-30	**30**	**1**	**1**	**0.034**	**-0.960**	**0.073**	0.039
31-35	**35**	**1**	**2**	**0.069**	**-0.776**	**0.114**	0.045
36-40	**40**	**0**	**2**	**0.069**	**-0.591**	**0.164**	0.095
41-45	**45**	**0**	**2**	**0.069**	**-0.406**	**0.223**	0.154
46-50	**50**	**2**	**4**	**0.138**	**-0.221**	**0.287**	0.149
51-55	**55**	**2**	**6**	**0.207**	**-0.037**	**0.354**	0.147
56-60	**60**	**6**	**12**	**0.414**	**0.148**	**0.422**	0.008
61-65	**65**	**3**	**15**	**0.517**	**0.333**	**0.488**	0.029
66-70	**70**	**4**	**19**	**0.655**	**0.517**	**0.551**	0.104
71-75	**75**	**3**	**22**	**0.759**	**0.702**	**0.609**	0.149
76-80	**80**	**0**	**22**	**0.759**	**0.887**	**0.662**	0.096
81-85	**85**	**1**	**23**	**0.793**	**1.072**	**0.710**	0.083
86-90	**90**	**1**	**24**	**0.828**	**1.256**	**0.752**	0.075
91-95	**95**	**2**	**26**	**0.897**	**1.441**	**0.789**	0.107
96-100	**100**	**1**	**27**	**0.931**	**1.626**	**0.821**	0.110
101-105	**105**	**0**	**27**	**0.931**	**1.810**	**0.849**	0.082
106-110	**110**	**0**	**27**	**0.931**	**1.995**	**0.873**	0.058
111-115	**115**	**1**	**28**	**0.966**	**2.180**	**0.893**	0.072
116-120	**120**	**0**	**28**	**0.966**	**2.365**	**0.910**	0.055
121-125	**125**	**0**	**28**	**0.966**	**2.549**	**0.925**	0.041
126-130	**130**	**0**	**28**	**0.966**	**2.734**	**0.937**	0.028
131-135	**135**	**0**	**28**	**0.966**	**2.919**	**0.947**	0.018
136-140	**140**	**0**	**28**	**0.966**	**3.103**	**0.956**	0.009
141-145	**145**	**0**	**28**	**0.966**	**3.288**	**0.963**	0.002
146-150	**150**	**0**	**28**	**0.966**	**3.473**	**0.969**	0.004
151-155	**155**	**0**	**28**	**0.966**	**3.658**	**0.975**	0.009
156-160	**160**	**0**	**28**	**0.966**	**3.842**	**0.979**	0.013
161-165	**165**	**0**	**28**	**0.966**	**4.027**	**0.982**	0.017
166-170	**170**	**0**	**28**	**0.966**	**4.212**	**0.985**	0.020
171-175	**175**	**0**	**28**	**0.966**	**4.396**	**0.988**	0.022
176-180	**180**	**0**	**28**	**0.966**	**4.581**	**0.990**	0.024
181-185	**185**	**0**	**28**	**0.966**	**4.766**	**0.992**	0.026
186-190	**190**	**0**	**28**	**0.966**	**4.951**	**0.993**	0.027
191-195	**195**	**0**	**28**	**0.966**	**5.135**	**0.994**	0.029
196-200	**200**	**0**	**28**	**0.966**	**5.320**	**0.995**	0.030

Appen Kolmogorov-Smirnov rs(2 hrs) AMS

201-205	**205**	0	**28**	**0.966**	**5.505**	**0.996**	0.030
206-210	**210**	0	**28**	**0.966**	**5.689**	**0.997**	0.031
211-215	**215**	0	**28**	**0.966**	**5.874**	**0.997**	0.032
216-220	**220**	1	**29**	**1.000**	**6.059**	**0.998**	**0.002**
	0.149< 0.246 null hypothesis is accepted at 0.05 level significance						

dix 26 test 6 Hou

			Kolmogorov Test				
Range	**Upper boundare**	**OFΣ**	**CUMULATIVE**	**Fo(X)**	**REDURED VARIABLE**	**Ft(U)**	**I Ft(u) - Fo(X) I**
31-35	**35**	**1**	**1**	**0.034**	**-0.924**	**0.081**	0.046
36-40	**40**	**0**	**1**	**0.034**	**-0.739**	**0.123**	0.089
41-45	**45**	**0**	**1**	**0.034**	**-0.554**	**0.175**	**0.141**
46-50	**50**	**3**	**4**	**0.138**	**-0.369**	**0.235**	0.097
51-55	**55**	**1**	**5**	**0.172**	**-0.185**	**0.300**	0.128
56-60	**60**	**4**	**9**	**0.310**	**0.000**	**0.368**	0.058
61-65	**65**	**3**	**12**	**0.414**	**0.185**	**0.435**	0.022
66-70	70	**6**	**18**	**0.621**	**0.369**	**0.501**	0.120
71-75	75	**3**	**21**	**0.724**	**0.554**	**0.563**	0.161
76-80	80	**0**	**21**	**0.724**	**0.739**	**0.620**	0.104
81-85	85	**0**	**21**	**0.724**	**0.924**	**0.672**	0.052
86-90	90	**1**	**22**	**0.759**	**1.108**	**0.719**	0.040
91-95	95	**3**	**25**	**0.862**	**1.293**	**0.760**	0.102
96-100	100	**1**	**26**	**0.897**	**1.478**	**0.796**	0.101
101-105	105	**0**	**26**	**0.897**	**1.663**	**0.827**	0.069
106-110	110	**1**	**27**	**0.931**	**1.847**	**0.854**	0.077
111-115	115	**1**	**28**	**0.966**	**2.032**	**0.877**	0.088
116-120	120	**0**	**28**	**0.966**	**2.217**	**0.897**	0.069
121-125	125	**0**	**28**	**0.966**	**2.402**	**0.913**	0.052
126-130	130	**0**	**28**	**0.966**	**2.586**	**0.927**	0.038
131-135	135	**0**	**28**	**0.966**	**2.771**	**0.939**	0.026
136-140	140	**0**	**28**	**0.966**	**2.956**	**0.949**	0.016
141-145	145	**0**	**28**	**0.966**	**3.141**	**0.958**	0.008
146-150	150	**0**	**28**	**0.966**	**3.325**	**0.965**	0.001
151-155	155	**0**	**28**	**0.966**	**3.510**	**0.971**	0.005
156-160	160	**0**	**28**	**0.966**	**3.695**	**0.975**	0.010
161-165	165	**0**	**28**	**0.966**	**3.880**	**0.980**	0.014
166-170	170	**0**	**28**	**0.966**	**4.064**	**0.983**	0.017
171-175	175	**0**	**28**	**0.966**	**4.249**	**0.986**	0.020
176-180	180	**0**	**28**	**0.966**	**4.434**	**0.988**	0.023

Appen ***rs(2 hrs) AMS***

181-185	185	**0**	**28**	**0.966**	**4.619**	**0.990**	0.025
186-190	190	**0**	**28**	**0.966**	**4.803**	**0.992**	0.026
191-195	195	0	**28**	**0.966**	**4.988**	**0.993**	0.028
196-200	200	0	**28**	**0.966**	**5.173**	**0.994**	0.029
201-205	205	0	**28**	**0.966**	**5.358**	**0.995**	0.030
206-210	210	0	**28**	**0.966**	**5.542**	**0.996**	0.031
211-215	215	0	**28**	**0.966**	**5.727**	**0.997**	0.031
216-220	220	1	**29**	**1.000**	**5.912**	**0.997**	0.003
	0.141 < 0.246 null hypothesis is accepted at 0.05 level significance						

Appen dix 27 Kolmogorov-Smirnov test 12 Hours(12 hrs) AMS

31-35	**35**	**1**	**1**	**0.034**	**-0.906**	**0.084**	**0.050**
36-0	**40**	**0**	**1**	**0.034**	**-0.725**	**0.127**	**0.092**
41-45	**45**	**0**	**1**	**0.034**	**-0.544**	**0.179**	**0.144**
46-50	**50**	**3**	**4**	**0.138**	**-0.362**	**0.238**	**0.100**
51-55	**55**	**1**	**5**	**0.172**	**-0.181**	**0.302**	**0.129**
56-60	**60**	**4**	**9**	**0.310**	**0.001**	**0.368**	**0.058**
61-65	**65**	**4**	**13**	**0.448**	**0.182**	**0.435**	**0.014**
66-70	70	**5**	**18**	**0.621**	**0.363**	**0.499**	**0.122**
71-75	75	**3**	**21**	**0.724**	**0.545**	**0.560**	**0.164**
76-80	80	**0**	**21**	**0.724**	**0.726**	**0.617**	**0.108**
81-85	85	**0**	**21**	**0.724**	**0.908**	**0.668**	**0.056**
86-90	90	**1**	**22**	**0.759**	**1.089**	**0.714**	**0.044**
91-95	95	**3**	**25**	**0.862**	**1.271**	**0.755**	**0.107**
96-100	100	**1**	**26**	**0.897**	**1.452**	**0.791**	**0.105**
101-105	105	**0**	**26**	**0.897**	**1.633**	**0.823**	**0.074**
106-110	110	**0**	**26**	**0.897**	**1.815**	**0.850**	**0.047**
111-115	115	**1**	**27**	**0.931**	**1.996**	**0.873**	**0.058**
116-120	120	**0**	**27**	**0.931**	**2.178**	**0.893**	**0.038**
121-125	125	**1**	**28**	**0.966**	**2.359**	**0.910**	**0.056**
126-130	130	**0**	**28**	**0.966**	**2.541**	**0.924**	**0.041**
131-135	135	**0**	**28**	**0.966**	**2.722**	**0.936**	**0.029**
136-140	140	**0**	**28**	**0.966**	**2.903**	**0.947**	**0.019**
141-145	145	**0**	**28**	**0.966**	**3.085**	**0.955**	**0.010**
146-150	150	**0**	**28**	**0.966**	**3.266**	**0.963**	**0.003**
151-155	155	**0**	**28**	**0.966**	**3.448**	**0.969**	**0.003**
156-160	160	**0**	**28**	**0.966**	**3.629**	**0.974**	**0.008**
161-165	165	**0**	**28**	**0.966**	**3.811**	**0.978**	**0.013**
166-170	170	**0**	**28**	**0.966**	**3.992**	**0.982**	**0.016**
171-175	175	**0**	**28**	**0.966**	**4.173**	**0.985**	**0.019**
176-180	180	**0**	**28**	**0.966**	**4.355**	**0.987**	**0.022**
181-185	185	**0**	**28**	**0.966**	**4.536**	**0.989**	**0.024**
186-190	190	**0**	**28**	**0.966**	**4.718**	**0.991**	**0.026**
191-195	195	**0**	**28**	**0.966**	**4.899**	**0.993**	**0.027**
196-200	200	**0**	**28**	**0.966**	**5.080**	**0.994**	**0.028**
201-205	205	**0**	**28**	**0.966**	**5.262**	**0.995**	**0.029**
206-210	210	**0**	**28**	**0.966**	**5.443**	**0.996**	**0.030**
211-215	215	**0**	**28**	**0.966**	**5.625**	**0.996**	**0.031**
216-220	220	1	**29**	**1.000**	**5.806**	**0.997**	**0.003**

Appen ***Chi-square***

	0.164< 0.246 null hypothesis is accepted at 0.05 level significance

dix 28 ***test 24 Hours(24 hrs) AMS***

Range	Upper boundare	OFΣ	CUMULATIVE	Fo(X)	REDURED VARIABLE	Ft(U)	I Ft(u) - Fo(X) I
31-35	35	1	1	0.034	-0.922	0.081	0.046
36-40	40	0	1	0.034	-0.748	0.121	0.086
41-45	45	0	1	0.034	-0.573	0.170	0.135
46-50	50	1	2	0.069	-0.399	0.225	0.156
51-55	55	3	5	0.172	-0.225	0.286	0.114
56-60	60	2	7	0.241	-0.050	0.349	0.108
61-65	65	5	12	0.414	0.124	0.413	0.000
66-70	70	4	16	0.552	0.299	0.476	0.076
71-75	75	5	21	0.724	0.473	0.536	**0.188**
76-80	80	0	21	0.724	0.647	0.592	0.132
81-85	85	0	21	0.724	0.822	0.644	0.080
86-90	90	1	22	0.759	0.996	0.691	0.067
91-95	95	3	25	0.862	1.170	0.733	0.129
96-100	100	0	25	0.862	1.345	0.771	0.091
101-105	105	1	26	0.897	1.519	0.803	0.093
106-110	110	0	26	0.897	1.694	0.832	0.064
111-115	115	0	26	0.897	1.868	0.857	0.040
116-120	120	0	26	0.897	2.042	0.878	0.018
121-125	125	0	26	0.897	2.217	0.897	0.000
126-130	130	1	27	0.931	2.391	0.913	0.018
131-135	135	0	27	0.931	2.565	0.926	0.005
136-140	140	0	27	0.931	2.740	0.937	0.006
141-145	145	1	28	0.966	2.914	0.947	0.018
146-150	150	0	28	0.966	3.089	0.955	0.010
151-155	155	0	28	0.966	3.263	0.962	0.003
156-160	160	0	28	0.966	3.437	0.968	0.003
161-165	165	0	28	0.966	3.612	0.973	0.008
166-170	170	0	28	0.966	3.786	0.978	0.012
171-175	175	0	28	0.966	3.961	0.981	0.016
176-180	180	0	28	0.966	4.135	0.984	0.019
181-185	185	0	28	0.966	4.309	0.987	0.021
186-190	190	0	28	0.966	4.484	0.989	0.023

Appen Kolmogorov-Smirnov

191-195	195	0	**28**	**0.966**	**4.658**	**0.991**	0.025
196-200	200	0	**28**	**0.966**	**4.832**	**0.992**	0.027
201-205	205	0	**28**	**0.966**	**5.007**	**0.993**	0.028
206-210	210	0	**28**	**0.966**	**5.181**	**0.994**	0.029
211-215	215	0	**28**	**0.966**	**5.356**	**0.995**	0.030
216-220	220	1	**29**	**1.000**	**5.530**	**0.996**	0.004
	0.188 < 0.246 null hypothesis is accepted at 0.05 level significance						

dix 29 test (0.4 hrs analysis)

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-30	5	8	-3	9	1.8
30-35	7	3	4	16	2.285714
35-40	6	3	3	9	1.5
40-45	6	3	3	9	1.5
45-60	3	5	-2	4	1.333333
60-100	2	5	-3	9	0
>100	0	2	-2	4	0
	29	29			8.419

8.419 < 14.067 null hypothesis is accepted at 0.05 level of significance

Appendix 30 Chi-square test (0.7 hrs analysis)

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-40	6	9	-3	9	1.5
40-50	9	5	4	16	1.777778
50-55	5	1	4	16	3.2
55-60	3	2	1	1	0.333333
60-70	4	5	-1	1	0.25
70-100	2	5	-3	9	4.5
>100	0	2	-2	4	0
	29	29			11.56

11.56 < 14.067 null hypothesis is accepted at 0.05 level of significance

Appen Chi-square

Appendix 31 Chi-square test (2 hrs analysis)

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-45	4	6	-2	4	1
45-60	8	5	3	9	1.125
60-70	7	3	4	16	2.285714
70-90	7	6	1	1	0.142857
90-145	2	5	-3	9	4.5
145-200	1	2	-1	1	1
>200	0	2	-2	4	0
	29	29			10.05

10.05 < 14.067 null hypothesis is accepted at 0.05 level of significance

Appendix 32 Chi-square test (3 hrs analysis)

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-60	12	12	0	0	0
60-65	3	0	3	9	3
65-70	4	1	3	9	2.25
70-90	5	5	0	0	0
90-145	5	7	-2	4	0.8
145-200	0	3	-3	9	0
>200	0	1	-1	1	0
	29	29			6.05

6.05 < 14.067 null hypothesis is accepted at 0.05 level of significance

Appendix 33 Chi-square test (12 hrs analysis

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-60	9	10	-1	1	0.111111
60-65	4	1	3	9	2.25
65-70	5	2	3	9	1.8
70-90	4	5	-1	1	0.25
90-145	6	7	-1	1	0.166667
145-200	0	2	-2	4	0
>200	1	2	-1	1	0
	29	29			4.578

4.578 < 14.067 null hypothesis is accepted at 0.05 level of significance

Appendix 34 Chi-square test (24 hrs analysis)

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-60	7	10	-3	9	1.285714

Appen Chi-square

60-65	5	1	4	16	3.2
65-70	4	1	3	9	2.25
70-90	6	5	1	1	0.166667
90-145	6	8	-2	4	0.666667
145-200	0	2	-2	4	0
>200	1	2	-1	1	0
	29	29			7.569

7.569 < 14.067 null hypothesis is accepted at 0.05 level of significance

dix 35 test (1 hr analysis)

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-40	4	6	-2	4	1
40-50	7	5	2	4	0.571429
50-55	3	2	1	1	0.333333
55-60	6	1	5	25	4.166667
60-70	3	6	-3	9	3
70-100	5	6	-1	1	0.2
>100	1	3	-2	4	0
	29	29			9.271

9.271 < 14.067 null hypothesis is accepted at 0.05 level of significance

Appendix 36 Chi-square test (1 hr analysis)

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-60	9	9	0	0	0
60-65	3	2	1	1	0.333333
65-70	6	1	5	25	4.166667
70-90	4	6	-2	4	1
90-145	6	7	-1	1	0.166667
145-200	0	3	-3	9	0
>200	1	1	0	0	0

	29	29			5.667

9.271 < 14.067 null hypothesis is accepted at 0.05 level of significance

Appendix 37 Chi-square test (1 hr analysis)

RANGE	O	E	O-E	(O-E)2	(O-E)2/E
0-5	1	1	0	0	0
5-10	0	0	0	0	0
10-15	2	4	-2	4	1
15-20	6	4	2	4	1
20-25	14	5	9	81	16.2
25-30	3	1	2	4	4
>30	3	14	-11	121	8.642857
	29	29			30.84

30.84 < 14.067 null hypothesis is rejected at 0.05 level of significance

Appendix 38 Sample of Rainfall Data Gathered

	Heavy Falls of Rain									
	Station: …….	Koforidua								
	Duration of Period	0.2 hours	0.4 hours	0.7 hours	1 hours	2 hours	3 hours	6 hours	12 hours	24 hours
	Lower limits of falls entered	12mm	15mm	20mm	25mm	25mm	30mm	30mm	30mm	40mm
Year	Month									
1967	12					25	28	33		
	max									
1968	1	13	25	31	33	38				
1968	4		15	23	28	43		46		
1968	5	25	64	71	74		31	33		
1968	6	20	33	46	48	56	58	64	66	66
1968	7	13	20	25	28	31	31	56	69	69
1968	8	15	18	20						
1968	9	15	25	33	36	41	41	41	56	
1968	10		15							

	Appen	***Chi-square***								
1968	11	13	18	23	25					
1969	1	15	25	305	305	305	305	31		
1969	3	15	25	38	41	41	41	41	41	41
1969	4	15	15	20						
1969	5	13	19	25	36	46	46	48	48	51
1969	10		18	23	25	31	36			
1971	5	31	43	69	71	99	99	99	99	
1971	10		20		51					
1972	2	18	23	38	43	46	46	46	46	46
1972	3			23		28	31			
1972	4	15	23	38	42	41		43		
1972	5	14	20	25	25	25	29	33		
1972	6	20	25	37	38	38	38	38	38	38
1972	7		19	20						
1972	9	19	29	33	48	51	51	51	51	51
1972	10	25	31	53	56	56	56	56	56	56
1973	2	25	51	66	76	76	76	76	76	76
1973	3	15	25	28	31	33	46	51	56	
1973	4	15	33	36	38	38	41	41	41	41
1973	5	18	23	28	31	33	36	36	38	38
1973	6	18	28	51	58	84	91	94	94	94
1973	7		18	20						
1973	8	20	25	38	48	48	48	48	48	48
1973	9	15	20	28	31	31	31	31		
1973	12	13	20	23	31	38	38	48	48	58
1974	3	18	23	41	43	51	53	58	61	61
1974	4	13	20	28	31	31	31	33		
1974	5	13	28	28	28	28	28			

1974	6	13	23	25	25	25	25			
1974	7	13	23	28	31	36	36	36	38	38
1974	8	13	18	31	38	46	46	46	46	46
1974	9	18	33	43	61	69	91	109	122	142
1974	10	18	23	23	31	31	33	43	43	43
1974	11	13	15							

1974	12	25	38	38	64	81	81	86	86	86
1975	2		15							
1975	3	20	33	41	41	41	43	43	43	43
1975	5	13	20	20						
1975	6	15	25	31	31	31	33	33	33	33
1975	7		25	34	52	69	82	93	93	93
1975	9	15	20	20						
1975	10	23	36	38	38	38	38	38	38	48
1975	11		15							
1976	2	19	37	42	42	44	47	46	47	47
1976	4	25	45	64	71	71	71	71	71	71
1976	5	16	25	28	28					
1976	6	18	24	26	29	37	38	38		
1976	9	15	26	33	33	33	33	33		
1976	11	22	33	33	33	33	33	33		
1977	3	14	39	47	48	48	48	48	48	48
1977	4	17	20	23						
1977	5	14	40	53	59	63	63	63	63	63
1977	6	25	50	70	70	70	70	70	70	70
1977	7	17	35	66	69	71	71	71	71	71
1977	9	15	24	28	32	32	32	32		
1977	10	25	40	46	48	48	48	67	69	69
1977	11	17	25	40	53	56	56	56	56	56
1977	12	18	36	37	37	37	37	37		
1978	2	19	21	31	31	31	31	31		
1978	3	13	24	27	29	29	29			
1978	4	17	29	31	32	33	33	33		
1978	5	20	27	34	35	35	35	42	46	46
1978	6	25	26	27	27	32	35	49	50	
1978	9		16							

1978	10	23	42	42	42	28	28			
1978	12	22	33	35	35	35	35	35		
1979	2	13	26	34	35	35	35	35		
1979	4	22	25	37	43	45	45	45	45	45
1979	5	13	18	22		37	37	39		
1979	6	14	22	25	26	28	45	51	51	51
1979	7	23	23	31	32	35	36	40	40	40
1979	8	15	25	38	47	50	52	52	52	52
1979	9	21	31	40	45	72	74	91	92	92
1979	11	18	29	37	37	37	37	37	37	
1980	1	24	30	34	34	34	34	34	34	
1980	2	18	25	25	25	25	25			
1980	4	16	34	37	37	43	43	43	43	43
1980	5	16	25	26	27	27	29	33	33	
1980	6	16	23	43	53	53	53	53	53	53
1980	7	19	24	26	28	34	39	49	49	49
1980	8	16	32	42	48	53	53	53	53	53
1980	9	25	32	37	37	34	34	34	34	
1980	10			21		25	25			
1980	11	19	26	30	33	33	33	33	33	
1981	2	15	27	28	29	29	29			
1981	3	19	38	51	59	66	69	70	72	72
1981	6		15					44	44	44
1981	7	17	17	36	27	31	42		47	47
1981	8	15	17							
1981	9	17	19	32	38	39	39	39	39	
1981	10	15	17							
1982	2	28	50	55	57	57	57	57	57	57
1982	3	12	32	39	39	42	48	75	56	75
1982	5	18	25	36	38	39	40	43	43	43
1982	6	19	31	31	39	40	40	47	47	47

1982	7	15	24	27	28	29	30			
1982	8	14	20	21						
1982	9	13	22	27	27	27	27			
1982	10		41	41	47	47	47	47	47	47
1982	11	19	25	27	27	27	27			
1982	12	14	15							
1983	3	17	19	21	35	63	65	65	65	65
1983	4	13	24	36	40	45	45	45	45	45
1983	5	20	37	43	39	42	43	44		
1983	6	14	17							
1983	10	21	33	33	33	33	45	62	62	
1984	8		19	31	40	40	40	40	40	40
1984	9		15	21	26	43	55	56	59	59
1984	10	15	15	20			25	43	43	43
1985	4	13	17							
1985	5	21	30	39	40	40	50	50	50	50
2001	5	33	30	43	47	50	53	55	56	56
2001	6	20	36	52	57	167	217	219	219	219
2001	9	21	25	39	40	42	43	44	44	44
2001	11	13	29	54	57	57	57	57	57	57
2002	3	35	40	54	59	61	61	63	63	63
2002	4	21			47	47	47	47	47	47
2002	5	15	20	22	56	67	67	67	67	64
2002	6		23	29		42	45	46	46	46
2002	7		21	29	35	37	47	48	48	71
2002	8		17					36	59	60
2002	9	13	25	46	47	47	47	47	47	47
2002	10		20	27	29	33	33	33	33	
2002	11		21	27	27	27	27			

2003	4	15	20	41	42	43	45	55	51	55
2003	5	13	18	24	36	38	38	38	38	38
2003	6		31	34	50	57	58	66	67	66
2003	7	14	27	28						
2003	10	20	32	35	34	39	42	48	48	48
2003	11	13	17	30	38	39	39	39	39	39
2004	6	20	72	77	101	102	113	113	114	127
2004	9	20	24	41	42	42	42	42	50	50
2004	11	27	18	44	44	51	57	57	51	51
2004	12	20	19	41	41	41	41	41	41	41
2005	3	12	33		44	48	48	48	48	48
2005	5		20	32	33	57	58	64	64	64
2005	8	17	27	40	45	49	50	50	50	50
2005	9	19	40	57	58	62	62	62	62	62
2005	10	13	19	22						
2005	11		16							
2005	12		20	25	25	29	29			
2006	1		43	43	43	43	43	43	43	43
2006	2	15	15	31	35	38	38	38	38	38
2006	3	12	30	34	34	34	34	34	34	34
2006	4	12	18	22	25	25				
2006	5	18	29	32	32	35	39	52	56	
2006	6	15	24	60	73	77	87	87	87	87
2006	7		16							
2006	9	24	28	32	33	33	37		37	
2006	10	22	32	35	42	44	51	51	51	51
2006	11	19	28	34	35	47	47	47	47	47
2007	1		24	34	37	37	37	37	37	
2007	3	17	31	41	42	43	43	43	43	43
2007	4	16	20	21		31	34	40	44	44
2007	5	15	27	30	31	31	31	31	31	

2007	6		20	24	28	32	32	35	38	
2007	7					37	42	49	52	52
2007	10	14	19	22	28	29	29	30	30	
2007	11	16								
2008	3		20	23	27	27	27			
2008	4	13	17	26	32	33	33	38	38	
2008	5	20	29	30	50	60	63		63	63
2008	6				37	54	58		58	58
2008	7		20	24	26	32	32		32	
2008	8	16	25	36	48	62	62		62	62
2008	10	14	21	23	32	34	34		34	
2008	12	14	17	23	33	33	33		33	
2009	1		19							
2009	2	16	21	41	52	56	67	67	67	67
2009	3	16	27	31	32	34	34	34	34	
2009	4	22	35	41	41	42	49	49	49	49
2009	5	20	34	46	49	51	51	51	51	51
2009	9		18							
2009	10	16	19	26	26	40	54	58	59	60
2009	11	15	21	21						
2009	12	19	23	24						
2010	1	23	26	27	27	27	27			
2010	2	28	44	56	66	67	67	67	67	67
2010	3		19	21						
2010	4	12		24	26	28	29			
2010	5	23	35	35	35	35	35			
2010	10	25	36	44	45	47	48	48	48	57
2011	3	13	15							

2011	4	17	34	47	48					

Appendix 39 Sample of Rainfall Data Gathered

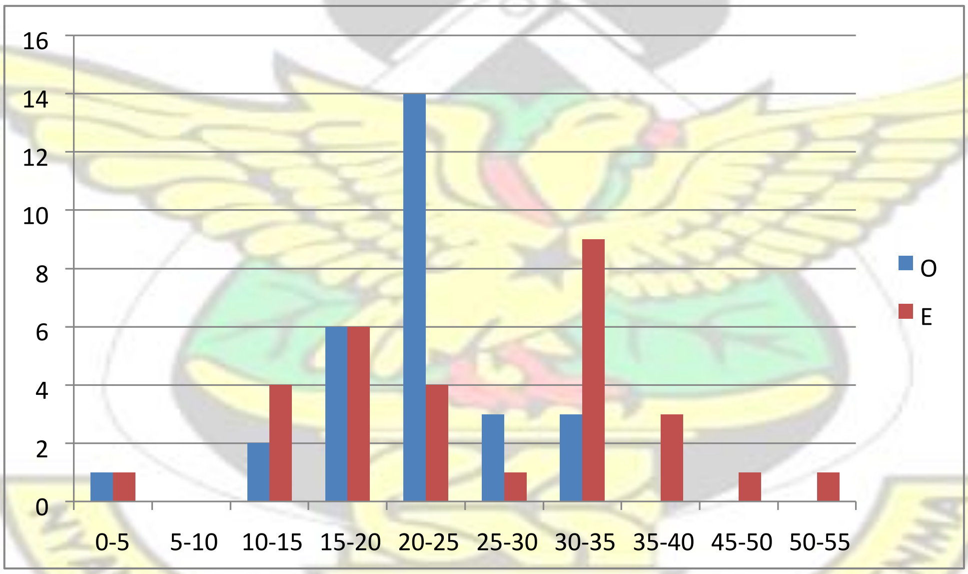
Duration	0.2hr	0.4hr	0.7hr	1hr	2hr	3hr	6hr	12hr	24hr
year	Rainfall Depth (mm)								
1967	4	13	20	23	25	28	33	34	34
1968	25	64	71	74	83	58	64	69	69
1969	15	25	38	41	46	46	48	48	51
1971	31	43	69	71	99	99	99	99	101
1972	25	31	53	56	56	56	56	56	56
1973	25	51	66	76	84	91	94	94	94
1974	25	38	43	64	81	91	109	122	142
1975	23	36	41	52	69	82	93	93	93
1976	25	45	64	71	71	71	71	71	71
1977	25	50	70	70	71	71	71	71	71
1978	25	42	42	42	35	35	49	50	51
1979	23	31	40	47	72	74	91	92	92
1980	25	34	43	53	53	53	53	53	53
1981	19	38	51	59	66	69	70	72	72
1982	28	50	55	57	57	57	75	57	75
1983	21	37	43	40	63	65	65	65	65
1984	15	19	31	40	43	55	56	59	59
1985	21	30	39	40	40	50	50	50	50
2001	33	36	54	57	167	217	219	219	219
2002	35	44	54	59	67	67	67	67	71
2003	20	32	41	50	57	58	66	66	67
2004	27	72	77	101	102	113	113	114	127
2005	19	40	57	58	62	62	64	64	64
2006	24	43	60	73	77	87	87	87	87
2007	17	35	43	48	53	57	59	60	61
2008	20	29	36	50	62	63	66	63	63
2009	22	35	46	52	56	67	67	67	67
2010	28	44	56	66	67	67	67	67	67
2011	17	34	47	48	53	57	60	61	62

Appen *Observed and Expected frequencies repartition*

dix 40

	REPARTITION FOR 0.2	
Range	O	**E**
0-5	1	1
5-10	0	0
10-15	2	4
15-20	6	6
20-25	14	4
25-30	3	1
30-35	3	9
35-40	0	3
45-50	0	1
50-55	0	1
	SUM=29	**SUM=29**

O: Observed Frequency; E: Expected Frequency



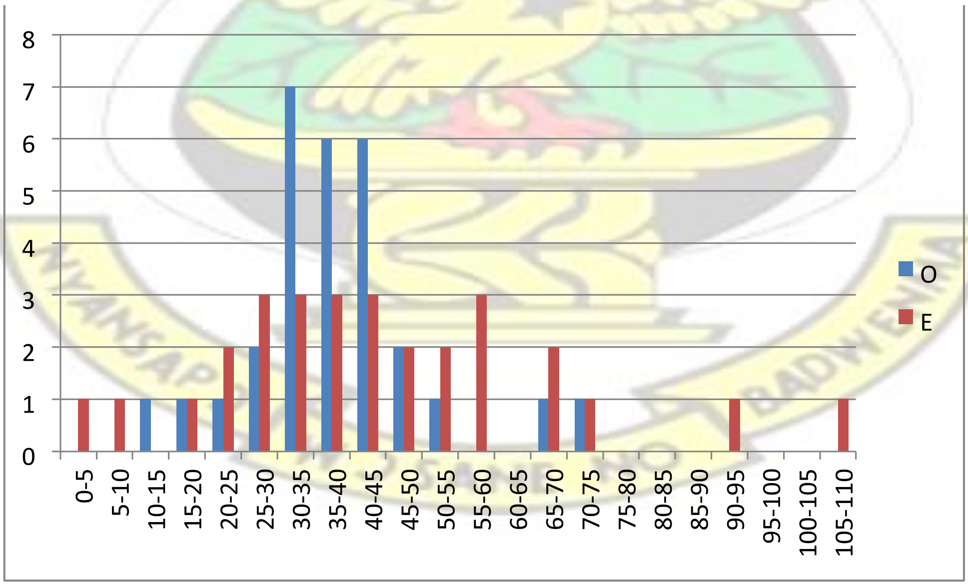
dix 41

REPARTITION FOR 0.4		
RANGE	O	E
0-5	0	1
5-10	0	1
10-15	1	0

Appen ***Observed and Expected frequencies repartition***

15-20	1	1
20-25	1	2
25-30	2	3
30-35	7	3
35-40	6	3
40-45	6	3
45-50	2	2
50-55	1	2
55-60	0	3
60-65	0	0
65-70	1	2
70-75	1	1
75-80	0	0
80-85	0	0
85-90	0	0
90-95	0	1
95-100	0	0
100-105	0	0
105-110	0	1
	SUM=29	SUM=29

O: Observed Frequency; E: Expected Frequency

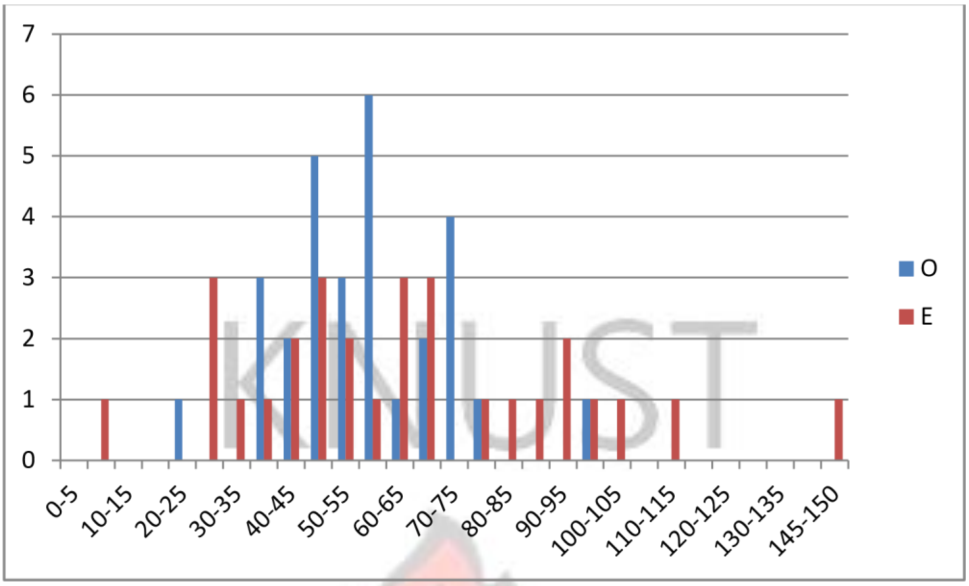


Appen ***Observed and Expected frequencies repartition***

dix 42

REPARTITION 1Hr		
RANGE	O	E
0-5	0	0
5-10	0	1
10-15	0	0
15-20	0	0
20-25	1	0
25-30	0	3
30-35	0	1
35-40	3	1
40-45	2	2
45-50	5	3
50-55	3	2
55-60	6	1
60-65	1	3
65-70	2	3
70-75	4	0
75-80	1	1
80-85	0	1
85-90	0	1
90-95	0	2
95-100	1	1
100-105	0	1
105-110	0	0
110-115	0	1
115-120	0	0
120-125	0	0
125-130	0	0
130-135	0	0
140-145	0	0
145-150	0	1
	SUM=29	SUM=29

O: Observed Frequency; E: Expected Frequency

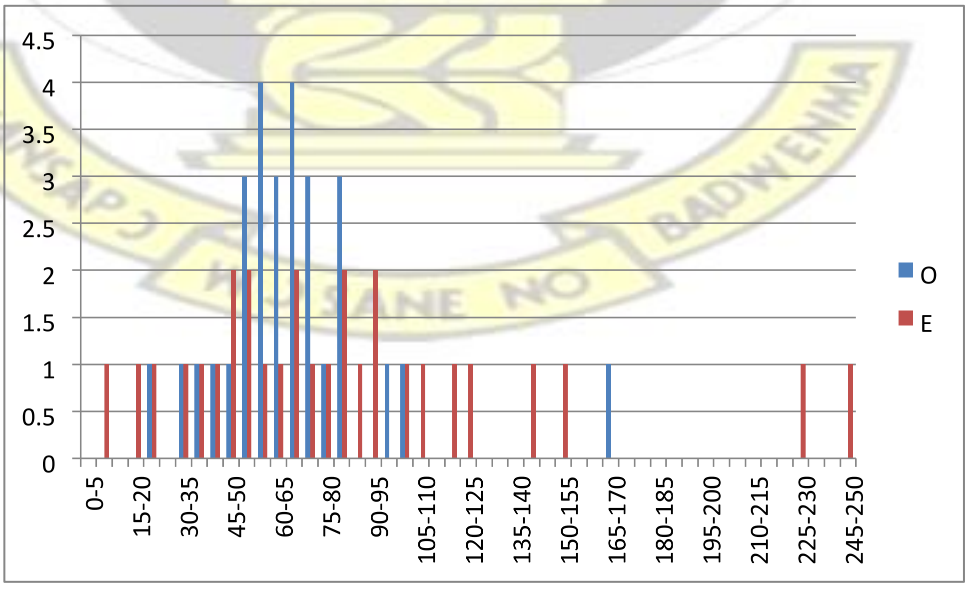


Appendix 43 Observed and Expected frequencies repartition

REPARTITION 2Hr		
RANGE	O	E
0-5	0	0
5-10	0	1
10-15	0	0
15-20	0	1
20-25	1	1
25-30	0	0
30-35	1	1
35-40	1	1
40-45	1	1
45-50	1	2
50-55	3	2
55-60	4	1
60-65	3	1
65-70	4	2
70-75	3	1
75-80	1	1
80-85	3	2
85-90	0	1
90-95	0	2
95-100	1	0
100-105	1	1
105-110	0	1
110-115	0	0
115-120	0	1

120-125	0	1
125-130	0	0
130-135	0	0
135-140	0	0
140-145	0	1
145-150	0	0
150-155	0	1
155-160	0	0
160-165	0	0
165-170	1	0
170-175	0	0
175-180	0	0
180-185	0	0
185-190	0	0
190-195	0	0
195-200	0	0
200-205	0	0
205-210	0	0
210-215	0	0
215-220	0	0
220-225	0	0
225-230	0	1
235-240	0	0
240-245	0	0
245-250	0	1
	SUM=29	29

O: Observed Frequency; E: Expected Frequency

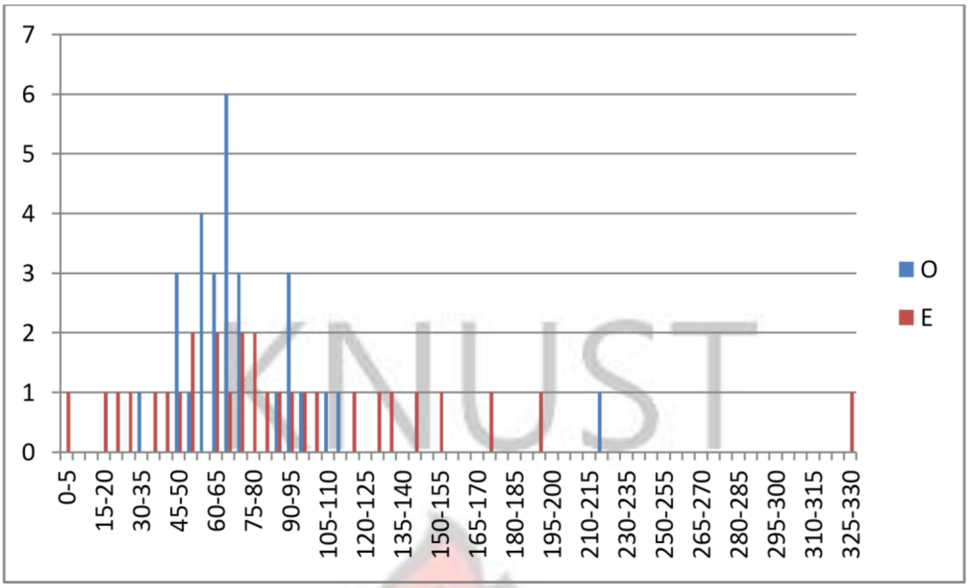


Appendix 44 Observed and Expected frequencies repartition

REPARTITION 6Hr		
RANGE	O	E
0-5	0	1
5-10	0	0
10-15	0	0
15-20	0	1
20-25	0	1
25-30	0	1
30-35	1	0
35-40	0	1
40-45	0	1
45-50	3	1
50-55	1	2
55-60	4	0
60-65	3	2
65-70	6	1
70-75	3	2
75-80	0	2
80-85	0	1
85-90	1	1
90-95	3	1
95-100	1	1
100-105	0	1
105-110	1	0
110-115	1	0
115-120	0	1
120-125	0	0
125-130	0	1
130-135	0	1
135-140	0	0
140-145	0	1
145-150	0	0
150-155	0	1
155-160	0	0
160-165	0	0
165-170		
170-175	0	1

175-180	0	0
180-185	0	0
185-190	0	0
190-195	0	1
195-200	0	0
200-205	0	0
205-210	0	0
210-215	0	0
215-220	1	0
225-230	0	0
230-235	0	0
235-240	0	0
245-250	0	0
250-255	0	0
255-260	0	0
260-265	0	0
265-270	0	0
270-275	0	0
275-280	0	0
280-285	0	0
285-290	0	0
290-295	0	0
295-300	0	0
300-305	0	0
305-310	0	0
310-315	0	0
315-320	0	0
320-325	0	0
325-330	0	1
	SUM=29	SUM=29

O: Observed Frequency; E: Expected Frequency


7
6
5
4
3
2
1
0
0-5
15-20
30-35
45-50
60-65
75-80
90-95
105-110
120-125
135-140
150-155
165-170
180-185
195-200
210-215
230-235
250-255
265-270
280-285
295-300
310-315
325-330
O
E

Appendix 45 CHI – SQUARE DISTRIBUTION TABLE

df	$\chi^2_{.995}$	$\chi^2_{.990}$	$\chi^2_{.975}$	$\chi^2_{.950}$	$\chi^2_{.900}$	$\chi^2_{.100}$	$\chi^2_{.050}$	$\chi^2_{.025}$	$\chi^2_{.010}$	$\chi^2_{.005}$
1	0.000	0.000	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.070	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.651	27.204	30.144	32.852	36.191	38.582
20	7.434	8.260	9.591	10.851	12.443	28.412	31.410	34.170	37.566	39.997
21	8.034	8.897	10.283	11.591	13.240	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	33.196	36.415	39.364	42.980	45.559
25	10.520	11.524	13.120	14.611	16.473	34.382	37.652	40.646	44.314	46.928
26	11.160	12.198	13.844	15.379	17.292	35.563	38.885	41.923	45.642	48.290
27	11.808	12.879	14.573	16.151	18.114	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	37.916	41.337	44.461	48.278	50.993
29	13.121	14.256	16.047	17.708	19.768	39.087	42.557	45.722	49.588	52.336
30	13.787	14.953	16.791	18.493	20.599	40.256	43.773	46.979	50.892	53.672
40	20.707	22.164	24.433	26.509	29.051	51.805	55.758	59.342	63.691	66.766
50	27.991	29.707	32.357	34.764	37.689	63.167	67.505	71.420	76.154	79.490
60	35.534	37.485	40.482	43.188	46.459	74.397	79.082	83.298	88.379	91.952
70	43.275	45.442	48.758	51.739	55.329	85.527	90.531	95.023	100.425	104.215
80	51.172	53.540	57.153	60.391	64.278	96.578	101.879	106.629	112.329	116.321
90	59.196	61.754	65.647	69.126	73.291	107.565	113.145	118.136	124.116	128.299
100	67.328	70.065	74.222	77.929	82.358	118.498	124.342	129.561	135.807	140.169